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AIR&SPACE Smithsonian

Fighter, Bomber, Hero, Sneak

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When UAVs Replace SUVs

How Computers Rate WWI Fighters

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Lockheed F-117A

JANUARY 2008

Love Potion #7?

The New Science of Love with a little wizardry thrown in.

In every great fairy tale, the sorcerers take a little science and throw in a little magic to create the perfect brew that brings two lovers together. Romance is all about chemistry and these seven brilliant stones can add just the right magical fire to raise the temperature of your secret potion. In today's most important design called the "River of Love", this pendant of 2 carats t.w. of graduated Diamond*Aura* stones is the perfect blend of science and sorcery. Our Gemologists have broken the code to create an impeccable stone with even more fire and better clarity than mined diamonds. Of course, the Diamond*Aura* stones are hard enough to cut glass and they are so clear and white that they rival a "D Flawless" diamond in terms of color and clarity. In the laboratory, we have found a way to match the brilliance and stunning reflective qualities of a diamond by using science and thus we avoid the outrageous price.

Perfection from the laboratory. We will not bore you with the details of the ingenious process, but will only say that it involves the use of rare minerals heated to an incredibly high temperature of over 5000˚F. This can only be accomplished inside some very modern and expensive laboratory equipment. After cutting and polishing, scientists finally created a faultless marvel that's optically brighter and clearer with more flashes of color. According to the book *Jewelry and Gems–the Buying Guide* the technique used in Diamond*Aura* offers, *"The best diamond simulation to date, and even some jewelers have mistaken these stones for mined diamonds."*

The 4 Cs. Our Diamond*Aura* jewelry retains every important specification: color, clarity, cut, and carat weight. In purely scientific measurement terms, ***the fire is actually superior to that of a diamond***. Fire is the dispersion of white light into a rainbow of color. Our team of cutters and polishers artistically performs the symmetrically brilliant, 58-facet cut to maximize the light reflection and refraction.

Compare For Yourself at 2 carats		
	Mined Flawless Diamond	Diamond*Aura* Compares to:
Hardness	Cuts Glass	Cuts Glass
Cut (58 facets)	Brilliant	Brilliant
Color	"D" Colorless	"D" Colorless
Clarity	"IF"	"F" Faultless
Dispersion/Fire	0.044	0.066
2 ct tw necklace	$20,000+	$129

Buying naturally mined diamonds can be a dangerous journey. Prices are high and often fixed, quality is subjective and the origins of the stones may be in doubt. Do you really want to worry about that or do you just want a look that is spectacular.

The "River of Love" is for that love of a lifetime. If you're looking for the most fire, carat weight, brilliance and clarity for a magnificent price, the 2 carat Diamond*Aura* "River of Love" 7 stone necklace is mounted in 18k gold fused over sterling silver for only $129.00! Just to make the magic more tempting, we will include the .86 total carat weight Diamond*Aura* stud earrings for FREE! If you are not thrilled with the brilliant romance of the Diamond*Aura* "River of Love" necklace, return it within 30 days for a refund of your purchase price and keep the stud earrings as our gift.

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Our scientifically impeccable DiamondAura Canary Ring displays the many hues of a radiant sunrise for only a fraction of the cost.

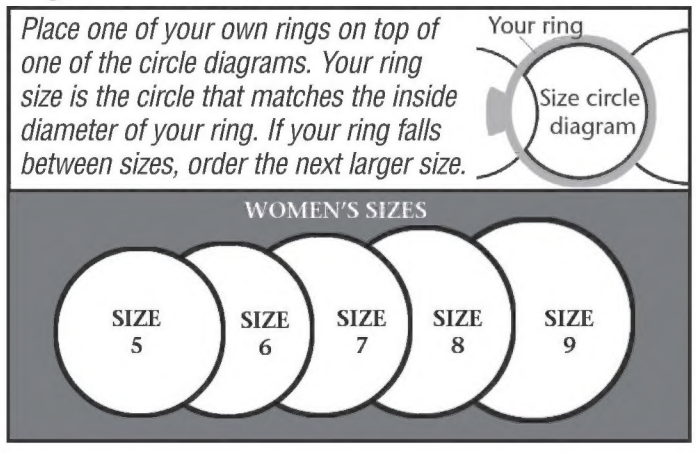
My 5th generation Belgian gem broker specializes in finding colored diamonds with a certain size, shape, color and clarity—he doesn't trade in what is available on the local market. During our visit, he proudly displayed a brilliant round-cut Canary diamond, explaining that natural yellow color diamonds are 10,000 times more rare than their brilliant white, colorless counterparts. He said this fine Canary Yellow gemstone, framed by two white diamonds, should retail for a minimum of $10,000. As my broker admired this treasure, I decided now was the time for a little amusement.

As he glanced away, I placed a similarly colored lab-created yellow Diamond*Aura* ring next to the natural mined diamond. My broker thought he was seeing double. After close examination, he was astonished—the faultless, lab-created oval-cut Diamond*Aura* was so visually similar in almost every way! He started to wonder about the future of the diamond business.

We were inspired by it's radiant color. Influenced by the ultra-rare Canary diamond, we went to the gemological laboratory to craft this extraordinary jewelry using lab-created Diamond*Aura*. Our Diamond*Auras* use rare minerals heated to over 5000 degrees in very expensive state-of-the-art lab equipment to create Diamond*Aura*. The ring features an oval-cut canary Diamond*Aura* set in the center with two oval-cut white Diamond*Auras* on either side, for a total carat weight of over 5.5 carats. The band is .925 sterling silver that won't tarnish over time. Truly affordable elegance!

Bring the beauty of a radiant sunrise to your own collection. If your ship has already come in, we will gladly sell you the ring with the natural mined Canary Yellow diamond at a cost of $10,000. But the labs at Diamond*Aura* give you a more affordable option at **only $149.85**. The choice is yours!

Place one of your own rings on top of one of the circle diagrams. Your ring size is the circle that matches the inside diameter of your ring. If your ring falls between sizes, order the next larger size.



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AIR&SPACE
Smithsonian

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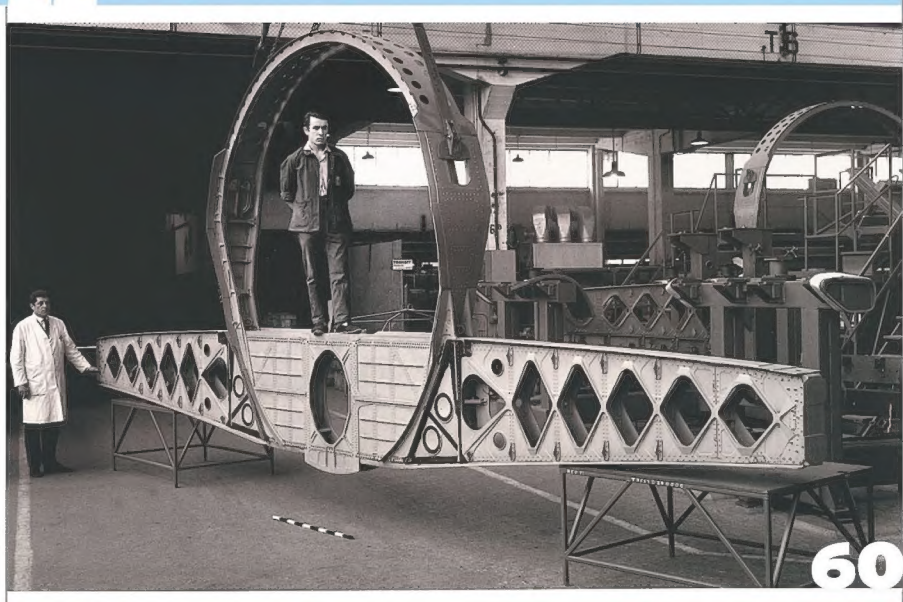

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On the cover: The F-117A Nighthawk in Bob Wickley's photo seems to have been chiseled from the mountains beneath it. In his retrospective on the first stealth fighter as it heads for retirement (p. 42), Bill Sweetman notes that the technology that made the aircraft look so freakish at birth matured quickly. We'll never see another like it.

Features

Departments

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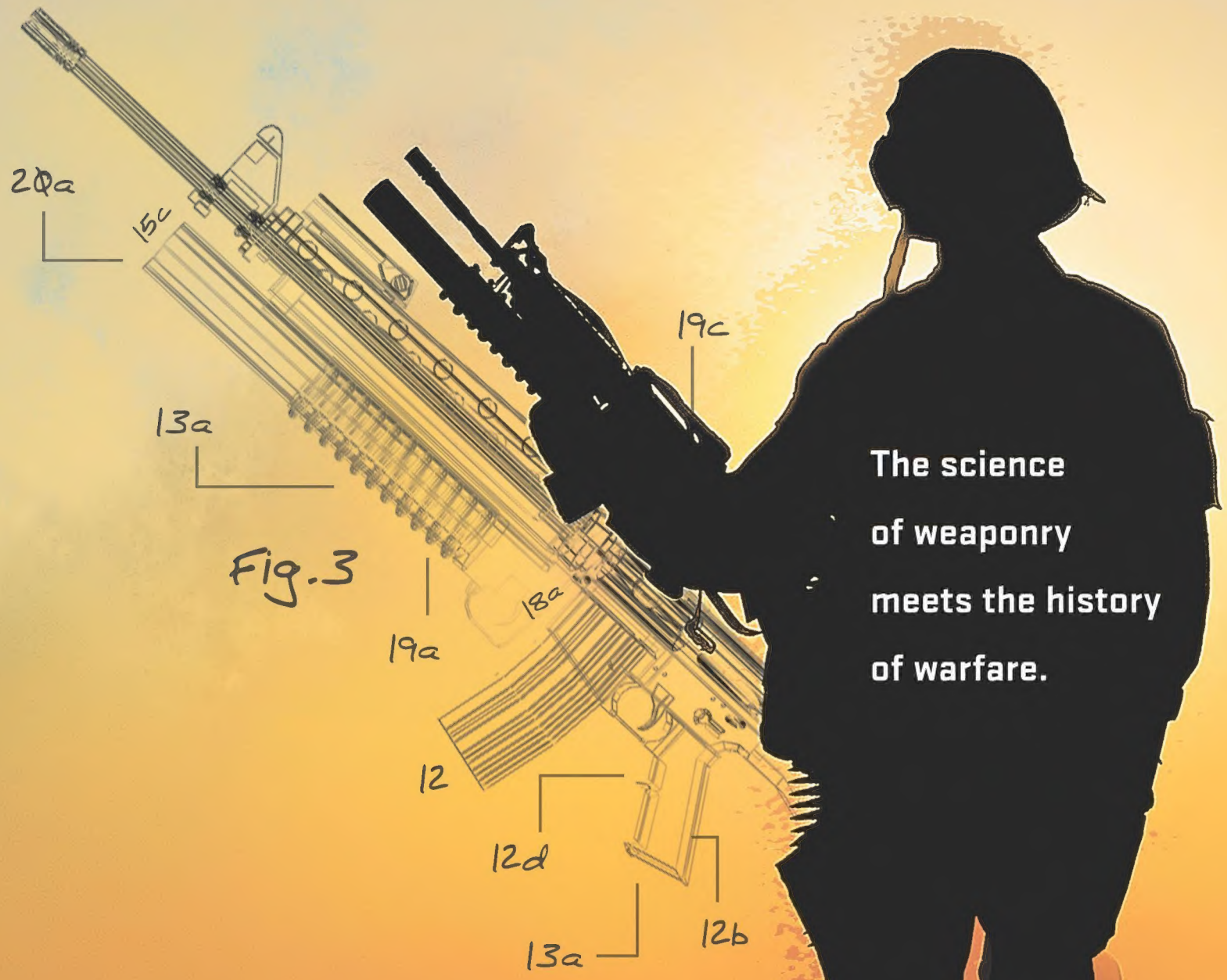

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AS A YEAR DRAWS TO AN END, it's customary to recall the achievements of the past 12 months and thank the people responsible for them. All of the staff members at the National Air and Space Museum deserve thanks for their hard work, but the additional "people power" we enjoy from our many volunteers plays such an important role in helping us serve our visitors, reach out to students, and otherwise conduct our business that I'd like to make a special mention of them. One of the most indefatigable groups among our volunteers is the NASM Docent Corps.

Recognized last year by the National Aeronautic Association with the most prestigious award in aerospace education, the Frank G. Brewer Trophy, the NASM docents are the "face" of the Museum. They represent the curators by passing along the bounty of curatorial knowledge to Museum visitors. They must be able to answer all of the questions that might reasonably arise on a Museum tour.

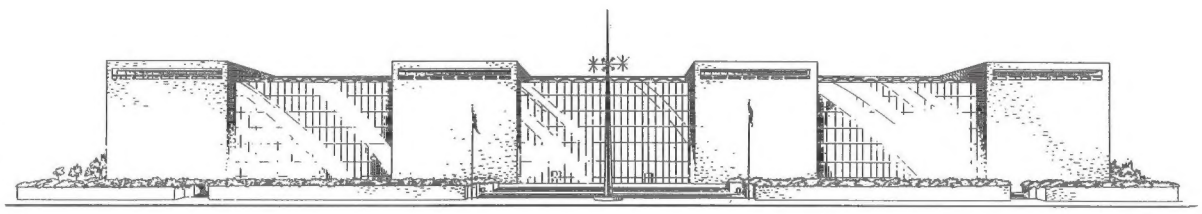
Many docents come to us already possessing a wealth of professional and personal experience in aviation and space-related activities, and all come with great enthusiasm. Background knowledge, however, is just part of what docents need to serve the NASM audience. Becoming a tour docent involves more than 80 hours of instruction in the history and technology of aerospace as well as in the techniques of leading interesting tours. Every novice docent also spends six months guiding tours with an experienced docent as a mentor. Ongoing training keeps the docents sharp. Additional training is available for docents to specialize in other aspects of the Museum learning experience.

The role of our docents is expanding too. They now offer tours aligned with national and local education standards to visiting school groups and perform as "on-air" talent in our growing videoconference distance learning program.

The NASM Docent Corps maintained its well-deserved reputation for excellence even during the opening of the Steven F. Udvar-Hazy Center in Virginia, when the scope of docent responsibilities more than doubled. Our docents not only had to cover two locations, they also had to help visitors appreciate the much larger subset of the total Museum collection now on exhibit.

During 2006, docents contributed more than 42,000 hours of service and enhanced the experience of more than 100,000 visitors to the Museum. They will exceed both marks in 2007. We could not serve the Museum's mission and our critical national educational needs without the dedicated service of our docents and all our volunteers.

J.R. DAILEY IS THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



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Letters

WRITE TO US

Death in a Cloud

Ewa Wisnierska's amazing survival tale ("Sucked Up," Above & Beyond, Oct./Nov. 2007) notes that another pilot at the Australia competition—Zongpin He—died of hypoxia and/or hypothermia. The coroner's report and Zhongpin's GPS track log show that the pilot in fact was struck by lightning at 16,150 feet and killed instantly.

Godfrey Wenness
via e-mail

Editors' note: The letter writer is a former paragliding distance world record holder and Organizer of the Fédération Aéronautique Internationale's 10th Paragliding World Championships of 2007.

A Ride with Amelia? No Thanks.

The recent 90th birthday of my mother, along with your June/July 2007 cover story on Amelia Earhart ("An American Obsession") and the mention of Zanesville, Ohio, in your Aug. 2007 issue ("Broadcast Bomber," Oldies & Oddities), motivated me to send on photos that brought all those things together.

On August 22, 1931, Amelia Earhart and her mechanic landed her Pitcairn PCA-2 at Wheeler field in Zanesville. Her mechanic, Eddie Vaught, called my grandfather, William Curtis, then sheriff of Muskingum County, to inquire where they could get aviation gas. My grandpa yelled to my then-14-year-old mother, Charlotte Love, "Come on Charlotte, we're going to see Amelia Earhart!" Her Pitcairn autogiro was a unique short-takeoff-and-landing craft that was intended to eliminate the need for a long runway. The big Wright R-975-E engine was thirsty, though, and needed frequent refueling.

Mom says she found Ms. Earhart very pleasant: greeting people, signing autographs, and passing out Beechnut gum. Amelia invited Mom to go up in her autogiro, but Mom declined. She said it looked too spindly and, with its stubby wings and big rotor, unlike any airplane she'd ever seen. It turned out that Amelia had crashed the craft a few weeks before when she dropped 30 feet, landing on two cars at Abilene, Kansas, and also a few weeks later when descending on the Michigan State Fair, so Mom's reluctance to fly with her was not without merit.

Daniel C. Love
Glendale, Ohio

Editors' note: For another picture of Earhart in Zanesville, see our Web site at www.airspacemag.com/scrapbook.

Soplata to the Rescue

In 1996, I and a group of other enthusiasts at Chrysler were working to create a corporate museum. One of my jobs was to find an XI-2220 inverted V-16 aircraft engine, designed and built by Chrysler in World War II. Only three remained: two in museums, and one in Walter Soplata's collection ("The Soplata Airplane Sanctuary," Oct./Nov. 2007).

On June 29, I visited Mr. Soplata, and sure enough, he had a pile of historic aircraft engines, including the XI-2220. In the next months, we arranged a swap, retrieved the engine,

Charlotte Love (right) turned down Earhart's offer of an autogiro jaunt.

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QC2 headphones (left). QC3 headphones (right).

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Letters

and refurbished it. It is now displayed in the Walter P. Chrysler Museum in Auburn Hills, Michigan.

We are all indebted to Walter and the Soplata family for saving valuable artifacts when almost no one else cared.

Bernard Robertson
via e-mail

Wally Soplata replies: "Dad got that engine in a batch of six or seven rare ones in 1963. All had 'U.S. Air Force Museum' decals on them. Dad was outraged that the museum had sold them for scrap."

Corrections

Oct./Nov. 2007 "The Real X-Men," p. 53: The photo on the left shows the crash site of Jack McKay, not Mike Adams.

"The Soplata Airplane Sanctuary": The C-82 is named the Packet, not the Boxcar.

"Pre-Flight and After Hours," Then & Now: Korean War-era Skyraiders should be referred to by the AD designation. The A redesignation occurred in the 1960s.

"Photos from the Attic," p. 45: The photo at the top is not a jet but a Northrop Delta 1D with a Wright Cyclone R-1820 radial engine.

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AIR&SPACE Smithsonian

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The recent U.S. Mint release of the new $1 Presidential Coins, some without the motto "In God We Trust," has numismatists digging into the history of the motto. The results revealed not only the first design attempting to use the motto, but led to the exclusive striking of this "lost" design for the VERY FIRST TIME!

The First Coin Design To Show…

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Proposed by James B. Longacre

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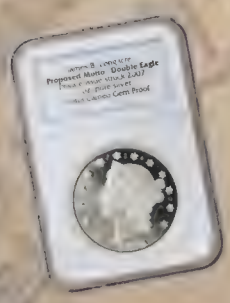
Why the shortened motto? Was the motto shortened to accommodate the smaller denomination? We'll never know, but now you can own a pure silver Proof of Longacre's first endeavor to convert U.S. coinage with this magnificent proposed-motto design—struck for the very first time from his actual sketches discovered in the numismatic vault at the Smithsonian Institution! Containing one ounce of .999 pure silver and struck to an ultra-cameo Gem Proof quality, this wonderful design commemorates a piece of American history and belongs in everyone's collection. Now you can secure the world's first and only "Our Trust Is In God" Double Eagle Proof for only $99 (plus S&H). CALL TODAY!



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Saving Jodie Foster's Telescope

The Arecibo radio telescope, which searched for ET signals in the movie *Contact*, now searches for funding.

>>> IN THE 1997 MOVIE *Contact*, the director of the National Science Foundation pulls up at Puerto Rico's Arecibo radio observatory and curtly informs rogue researcher Jodie Foster that he is cutting funds for locating signals from extraterrestrial intelligence. In a life-imitating-art twist, the NSF now plans to cut all funding for Arecibo by 2011—unless someone else can be found to share the costs.

The foundation wants to divert much of the $10.5 million it has spent annually on Arecibo into a new generation of telescopes that explore wavelengths in a less studied realm of the spectrum than radio. The decision, NSF officials point out, is the same as a recommendation made to the foundation in 2006 by an independent panel of astronomers looking for ways to stretch the NSF's limited funds.

Last September, researchers ranging from cosmologists to planetary geologists to asteroid hunters met in Washington, D.C., to make a case for saving the big radio telescope. "The community did not have a say in this," complains astronomer Steve Ostro of NASA's Jet Propulsion Laboratory in California, who spoke at the standing-room-only gathering. In particular, Ostro says, the planetary viewer that was upgraded a decade ago is "irreplaceable—it's the most sensitive radar on the planet."

Using radar waves, the 40-

UPDATE

All I Want for Christmas...

WITH A FLURRY OF EXCLAMATION POINTS, Neiman Marcus' Christmas Book catalog offers a Texas-size bargain: "your very own, totally tricked out racing team franchise. And not just cars – rockets, in the world's first aerospace racing league!" What it boils down to is the chance to sponsor a 2008 Rocket Racing League team (see "X-Racers," Sept. 2007). Your $2 million pays for the XCOR EZ-Rocket racer and trailer, training for pit crew and pilot, and a full year of ground support, equipment, parts, kerosene fuel, and oxidizer.

Picture your logo HERE – for a mere $2 million.

LEFT: ROCKET RACING LEAGUE; TOP: NAIC ARECIBO OBSERVATORY/NSF

year-old telescope can peer through the clouds of Venus, track the trajectory of an asteroid that may threaten Earth, or locate the massive spinning objects called pulsars. Arecibo has 20 times the seeing power of the next largest radio telescope, in Goldstone, California.

New York's Cornell University, which operates the telescope, intends to turn off the planetary viewer next October, since it costs $1 million a year to operate. While the university, which sponsored the September gathering in Washington, seeks non-NSF funding, it is not above pressing Congress to intervene. Members of the Hispanic caucus like Representative Jose Serrano of New York say they may step in to try to avert an Arecibo closure.

ANDREW LAWLER

Party Like It's 1957

>>> "I WAS NINE YEARS OLD when Sputnik changed my life," Northrop Grumman chairman and self-described space cadet Ron Sugar told the appreciative audience at the California Institute of Technology in Pasadena last September.

The remark was an appropriate opening to a conference marking the dawn of the Space Age 50 years ago. And it was made at an appropriate spot—a few miles from the Jet Propulsion Laboratory, home of the Explorer 1 satellite, which lifted off from Cape Canaveral, Florida, in early 1958, four months after Sputnik was launched.

Fittingly, two Explorer 1 engineers were on hand. So were NASA Administrator Mike Griffin, Caltech grad (and moonwalker) Harrison Schmitt, former Indian president A.P.J. Abdul Kalam, whom the country affectionately calls "Missile Man" for his science and engineering work, as well as students.

"We wanted to show young people what could be accomplished in a single lifetime," JPL director Charles Elachi explained.

"The first 50 years have given us a new view of the solar system, a view much richer than the terracentric view we had before the Space Age began," former JPL director Ed Stone said.

A model of the Mars Exploration Rover takes center stage at Caltech.

"I am a space engineer," said Gentry Lee, JPL's chief engineer for planetary flight systems. "In no other epoch could I have said, 'I am a space engineer.' What a wonderful thing to be!"

PRESTON LERNER

The CIA's High-Flying Spy

LAST SEPTEMBER, at its headquarters in McLean, Virginia, the Central Intelligence Agency unveiled a Lockheed A-12 that flew photo reconnaissance missions during the cold war and in Vietnam. Guests at the ceremony included engineers, photo analysts, project pilots, and family members of pilots who died during the top-secret A-12 project.

"Article 128," CIA code for A-12 serial number 60-06931, is one of only nine remaining (13 were built); the rest are on display at museums across the country. Article 128 had been on loan to the Minnesota Air National Guard from the Museum of the United States Air Force in Dayton, Ohio.

In the late 1950s, Lockheed Skunk Works, led by the visionary Kelly Johnson, competed for a CIA contract to build the successor to the U-2 high-altitude reconnaissance aircraft. The new aircraft would have to be fast enough to outrun any Soviet missile. Lockheed created the Mach 3-plus A-12, which reached 92,500 feet and would evolve into the SR-71 Blackbird. "The A-12 literally took people's breath away when they first saw it fly," CIA director General Michael V. Hayden told the audience. "[Former] director Richard Helms, recalling a midnight test flight in the Nevada desert, later wrote: 'The blast of flame that sent the black, insect-shaped projectile hurtling across the tarmac made me instinctively duck. It was as if the Devil himself were blasting his way straight from hell.' He had a gift for understatement."

The CIA's Article 128 made 232 flights in the early 1960s.

The A-12 was deployed to Kadena Air Base in Okinawa for Operation Black Shield. A cadre of A-12s and pilots overflew North Vietnam, Cambodia, and North Korea, imaging thousands of square miles. In 1968, Operation Black Shield was replaced by the SR-71 Air Force program.

CONNIE PARDEW

RIGHT: CIA; TOP: CALTECH

CSI: Airport

The Smithsonian Institution's Carla Dove, Marcy Heacker, and Nancy Rotzel (right to left) are striking a blow for airliner safety by identifying the types of birds that collide with aircraft.

>>> WHEN CARLA DOVE checks her mail each day, she finds a dozen packages from airport managers, pilots, and wildlife biologists around the world. The contents: mangled bird carcasses. These birds have been on the losing end of a collision with an aircraft. As the head of the Smithsonian Institution's Feather Identification Laboratory, it is Dove's job to identify the bird species from their remains.

About 25,000 birdstrikes occur each year in the United States alone, costing the civil aviation industry about $500 million. More importantly, strikes create the potential for human injury—or worse. Biologists, researchers, and those involved in airport safety hope that by identifying the species that are colliding with aircraft, bird strikes can be avoided.

Dove's team of three use microscopes to examine feather characteristics such as size, shape, pattern, color, and texture; comparing the findings to the 620,000 bird specimens in the Smithsonian's collection enables them to make matches. Recently, Dove and her colleagues have been turning to DNA "barcoding" as a means of species identification—especially when only what the researchers call "snarge"—small bits of blood and bird tissue—can be recovered.

Dove's team, in collaboration with colleagues at the University of Guelph in Canada, has recently completed a library of DNA sequences of bird species in the United States and Canada. Thanks to a five-year grant from the Federal Aviation Administration, 96 percent of U.S. and Canadian bird species (approximately 645) can now be identified from DNA.

Dove admits that identifying bird remains using DNA "is not easier, it's not cheaper, and it's not faster." However, "it has enabled us to improve our species-level identifications by about 30 percent," she says. "In the past we identified nearly 100 percent of the strikes, but some were only identified to the major group of birds, like order or family. Now we can get all the way down to the species level—like song sparrow."

But DNA sequencing was never expected to replace feather identification. Dove and her team still count on whole feathers and circumstantial evidence to identify birds.

JENNIFER A. LYNCH

UPDATE

"It's...ALIVE!"

ROBERT PLEMING, HEAD of the Vulcan to the Sky Trust, credits the "British bulldog spirit" for restoring Avro Vulcan XH558 to airworthy status (see "God Save the Vulcan!" Dec. 2003/Jan. 2004). The iconic cold war delta-wing bomber made a 20-minute flight last October at Bruntingthorpe Airfield in Leicestershire, after a $12 million overhaul, the vast majority of which was donated by Vulcan fans. The government's Heritage Lottery Fund had jump-started the restoration by awarding the project some $5 million in 2004. Pleming hopes the Vulcan will spend 15 years as an airshow star before retiring to a museum.

A Star is Airborne: Vulcan XH558 flies again.

LEFT: VULCAN TO THE SKY; TOP: JAMES DILORETO, SMITHSONIAN INSTITUTION

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A Dossier on Every Airliner

ONE DAY RECENTLY, Alexandre Avrane got a tip from a German contact: An airliner recently sold by a Thai carrier had received a fresh coat of paint in Jakarta. He posted it, along with around 50 other current bits of information, on his Web site, AeroTransport Data Bank, *www.aerotransport.org*. "New information every hour," he says. "An airliner bought, delivered, crashed. An airline just born, an airline which is closing."

Every day the 50-year-old Frenchman posts information on every airplane with 30 seats or more—170,000 in all. Much of the information comes to him from airport workers and "planespotters," hobbyists who track and report aircraft movement.

In 1972, Avrane began annotating a copy of *JP Airline Fleets International*, an annual catalog that lists every airliner in the world, and he created a database that eventually became the Web site. Avrane realized that organizations that lease airplanes would pay for such information as the number of owners an airplane had had, the hours it had flown, and repairs that had been made. Now the site has 1,400 subscribers who access it for $50 to $1,600, depending on what information they seek.

It's a one-man show. Avrane, who lives in Paris, says "I work late into the night because I need to wait for the guys in California. Most activities on the planet are on the West Coast."

PHIL SCOTT

>>> Air&Space Interview <<<

Michael J. Neufeld

CHAIR, SPACE HISTORY DIVISION, NATIONAL AIR AND SPACE MUSEUM, AND AUTHOR OF VON BRAUN: DREAMER OF SPACE, ENGINEER OF WAR *(KNOPF, 2007)*

NEUFELD HAS WRITTEN AN EXTENSIVELY researched account of the complicated life of Wernher von Braun. A rising star in the German army's rocket program, von Braun led the development of the seminal V-2 missile and was a loyal follower of the Third Reich. After the war, von Braun reinvented himself as a leader of the U.S. space program.

Was there any way von Braun could have repudiated the use of slave labor and still carried on his work as a rocket engineer?

That's been the traditional kind of defense: that he was trapped, that he couldn't do anything. But all the evidence is that he was quite comfortable with the Nazis and the Third Reich until late in the war. It was only in the last year or two of the war – through a combination of his last encounter with Hitler, witnessing concentration camp labor, and above all his own arrest by the Gestapo – that he became disillusioned about this regime. He bears some moral responsibility for seeing the horrible conditions and continuing to work day and night for that program with total commitment.

Neufeld spent 10 years studying the life of Wernher von Braun.

Did von Braun ever express remorse about the use of slave labor that transpired under the Nazi regime?

After the war, like so many others, he said, "I didn't know about the Holocaust." He also came to the realization that Hitler was an evil person. So he certainly distanced himself from that. Late in his life, in his 60s and 70s, he did express some remorse in letters about the concentration camp prisoners. But there's no great sense of guilt there. There was never any acceptance of personal responsibility for any of it.

In terms of his contributions to the development of rocket technology, where do you place von Braun?

Though I never liked him much as a person because I was repulsed by the moral compromises [he made during] the Third Reich, I had to conclude that he was probably the most important rocket engineer of the 20th century.

What made him a great manager of these large-scale engineering programs?

Obviously, he had the fundamental science and engineering background. He was not just a figurehead manager-type. And he was enormously charming and charismatic. People just wanted to follow him. After the war, a British correspondent described him: "As handsome as a film star – and he knows it." He was a ladies' man.

Visit *www.airspacemag.com* for the full interview.

CAROLYN RUSSO

Clockwise starting top left: Copper Canyon Train; Posada Barrancas Mirador; Posada Barrancas Mirador; El Fuerte River Float Trip; Traditional Mexican Dancer; On Train

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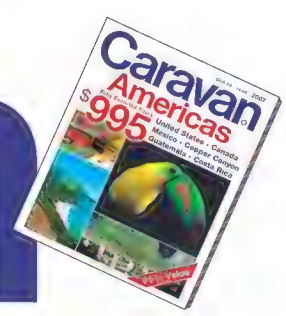

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One Aeronautical Laboratory, Boxed

In 1914, the Smithsonian asked Glenn Curtiss to rebuild Samuel Langley's Aerodrome (left, a quarter-scale model) in an attempt to rehabilitate the scientist's reputation. Nearly a century later, Rob Mawhinney, Peter Jakab, Ken Isbell, and Greg Cone (above) unpack the Curtiss modifications.

ERIC LONG (2)

HAD SAMUEL PIERPONT LANGLEY chosen to conclude his aeronautical experiments with the triumph of his little unmanned Aerodrome No. 6, which lifted off in front of cheering spectators and flew almost a mile before settling into the Potomac River, he would be remembered as an aviation genius. Unfortunately, he continued. That decision was also unfortunate for his mechanic, Charles Manly, who was dunked in the Potomac by the follow-on, much larger Aerodrome A, when it slid from its houseboat launch pad into the river "like a handful of mortar," according to a 1903 *Washington Post* article covering the attempted flight.

Langley died in 1906 after a series of strokes; in his eulogy for the former Secretary of the Smithsonian, Alexander Graham Bell referred to the scientist's bitter disappointment: "The newspapers did not treat Prof. Langley with fairness. Ridicule shortened his life." By 1918, much of Langley's workshop, tools, and models had been packed in crates and placed in storage—and the last of the crates would remain unopened for nearly a century.

On a warm day last September, Museum staff gathered at the Paul E. Garber Preservation, Restoration and Storage Facility in Suitland, Maryland, to open the remaining crates. Laid out in Building 7, along with a P-63 Kingcobra, an Ercoupe, and other airplanes, whole and in pieces, were hundreds of objects. Parts of Langley's aerodrome models—tiny, rough-hewn propellers, gasoline burners, water condensers, floats, and boilers—were neatly arranged on pallets, ready for cataloging.

Using Langley's own *Experiments in Aerodynamics* and *Memoir on Mechanical Flight*, Museum technician Ken Isbell painstakingly matched each object to the detailed drawings in Langley's books.

"I think these are this," curator Peter Jakab said to Isbell, pointing to a picture in *Memoir*. "They were tested on the whirling table in 1898-99. If that's what they are, Ken, we want to get them preserved. They're important."

"Here's a gate hinge," Isbell said, picking up a rust-covered object. "There's so much stuff, and half of it we don't know what it is."

Greg Cone, an early-flight expert with the Wright Experience in Warrenton, Virginia, was visiting to

help identify the pieces and was also stumped by some of them. "What this does I have no idea," he said. "The guy was a maniac when it came to scientific equipment. Langley left us mechanisms that might have been mistaken for gizmos from Jules Verne, or a Buck Rogers movie set."

After a crane removed the top of the largest crate, a cross-rib came to light, bearing a tag that read: "May 1918. Intermediate cross-rib taken from one of the wings used by Mr. Curtiss in the flights of the Langley Aerodrome in Hammondsport, NY in 1914." The crate contains other pieces of the aircraft that Glenn Curtiss refabricated before flying the Aerodrome from Lake Keuka in 1914. As dozens of history books record, Curtiss' attempt to rehabilitate Langley's reputation made Orville Wright furious.

The second crate revealed wings from one of the aerodrome models—in seemingly pristine condition. The fragile wings will remain in the crate until Isbell can catalog them.

When the final crate was opened, Greg Cone got a surprise. "This looks like a Wright brothers' strut and landing skids," he said. "They're definitely of that style." On closer inspection, he decided that the outboard wing strut was a Burgess-Wright. "Starling Burgess, a yacht builder in Massachusetts, had contracted with the Wrights to build a licensed copy of the Wright Model B airplane," he explained. "It was known as the Burgess-Wright Model F. Burgess planes were finished in gray paint. I know of no other Burgess-Wright F parts like these that survive. Sure wish we knew how these parts found their way to the Smithsonian."

Isbell estimates that it will take three to five years to catalog Langley's collection. The objects—immensely significant in the history of flight—will help historians assess the work and importance of Langley, a diverse scientist who made great contributions to astrophysics and mathematics but is remembered today—perhaps unfairly—for failing at manned flight. "One aspect of Langley's work shouldn't be highlighted over another," Jakab cautions. "It's all one integrated story." And Jakab will be writing that story in the years to come.

REBECCA MAKSEL

Visitor Information

Curator's Choice Occasionally a National Air and Space Museum curator gives a 15-minute talk related to the collection. On the National Mall, meet at noon in the Milestones of Flight gallery on the first floor. Dec. 5, The World War I Ace in Popular Culture. Dec. 19, Air Racing and the Golden Age.

What's Up Receive regular updates on Museum events, read about artifacts, get detailed (and behind-the-scenes) exhibition information, and receive calendar listings by subscribing to the National Air and Space Museum's free monthly e-newsletter, *What's Up*. Sign up at *www.nasm.si.edu*.

Docent Tours Docent-led tours highlight the Museum's collection and trace the history of air and space travel. Tours are conducted daily at 10:30 a.m. and 1 p.m. At the National Air and Space Museum on the Mall, meet at the Welcome Center. At the Steven F. Udvar-Hazy Center, meet at the Docent tours desk in the Boeing Aviation Hangar.

National Air and Space Society Members of the National Air and Space Society are charitable donors who support the mission and programs of the National Air and Space Museum. Society membership offers advance access, invitations to special events in the Museum, and other benefits. Like *Air & Space* associate members, National Air and Space Society members receive *Air & Space* magazine and discounts. Unlike associate members, Society members' contributions help fund the Museum's restoration, preservation, and education efforts. Both memberships support the Smithsonian Institution. For more information visit *www.nasm.si.edu/membership*.

ARTIFACTS

Unearthly Fashion

ONE OF THE MORE WHIMSICAL objects in the Museum's collection is this Space Age handbag, which pays tribute to Apollo 11, the first lunar landing. In 1969, as one in seven persons worldwide watched the televised event, astronauts Neil Armstrong and Buzz Aldrin walked on the moon while pilot Michael Collins orbited in the combined command-service module. Shaped like that module, which brought the astronauts back from the moon, the foot-long tote was created by a Canadian designer and presented to Collins upon his return; he offered it to NASM in 1972, upon becoming the Museum's first director.

Space artifacts from the Museum's collection – both lighthearted and serious – are highlighted in the book *After Sputnik*, which explores the first 50 years of achievement in space.

Space Shuttle Guest Book

WE SPACECRAFT OPERATORS in the Orbiter Processing Facility at the Kennedy Space Center in Florida have seen quite a parade of tourists in the past quarter-century. As part of our jobs working with the contractor companies that recover and prep shuttles for launch, my colleagues and I are often called upon to give tours, showing visitors around an orbiter at the request of a NASA official or a United Space Alliance manager. There were so many Congressmen and -women here for John Glenn's 1998 launch on *Discovery* that we ran out of clean room garment ensembles—bunny suits—and lawmakers were crawling around the orbiter in street clothes. (One particularly stout senator, who was having trouble negotiating the interdeck access hole, asked, "Did Senator Kennedy get in here?") Sometimes it's a Department of Defense officer, sometimes a worker's spouse, engineers from other NASA centers, governors, janitors, actors, newspeople, astronaut siblings, former Women Airforce Service Pilots, heads of state, Air Force Thunderbird pilots —we've seen them all, from Leonard Nimoy to Jacques Cousteau.

Sometimes we are surprised to hear

Orbiter Processing Facility III white room, where shuttle crews enter the orbiter, with signatures of Clint Eastwood, Florida governor Jeb Bush, space shuttle commander Eileen Collins, and a few hundred others.

Though our walls are not as moving as the Vietnam Veterans Memorial Wall, or as important as an airplane signed by thousands of assembly workers, we shuttle techs nonetheless wonder what will happen to this treasure when we recover the last shuttle mission in 2010.

visitors ask very knowledgeable questions; other times we watch them forget to duck, smacking their heads. Once I fell in love with a professor who was as sharp as she was beautiful. But none of the three bays where astronauts enter the orbiters has a guestbook. And although we've had some famous guests, no one has kept track for a Who's Who of visitors.

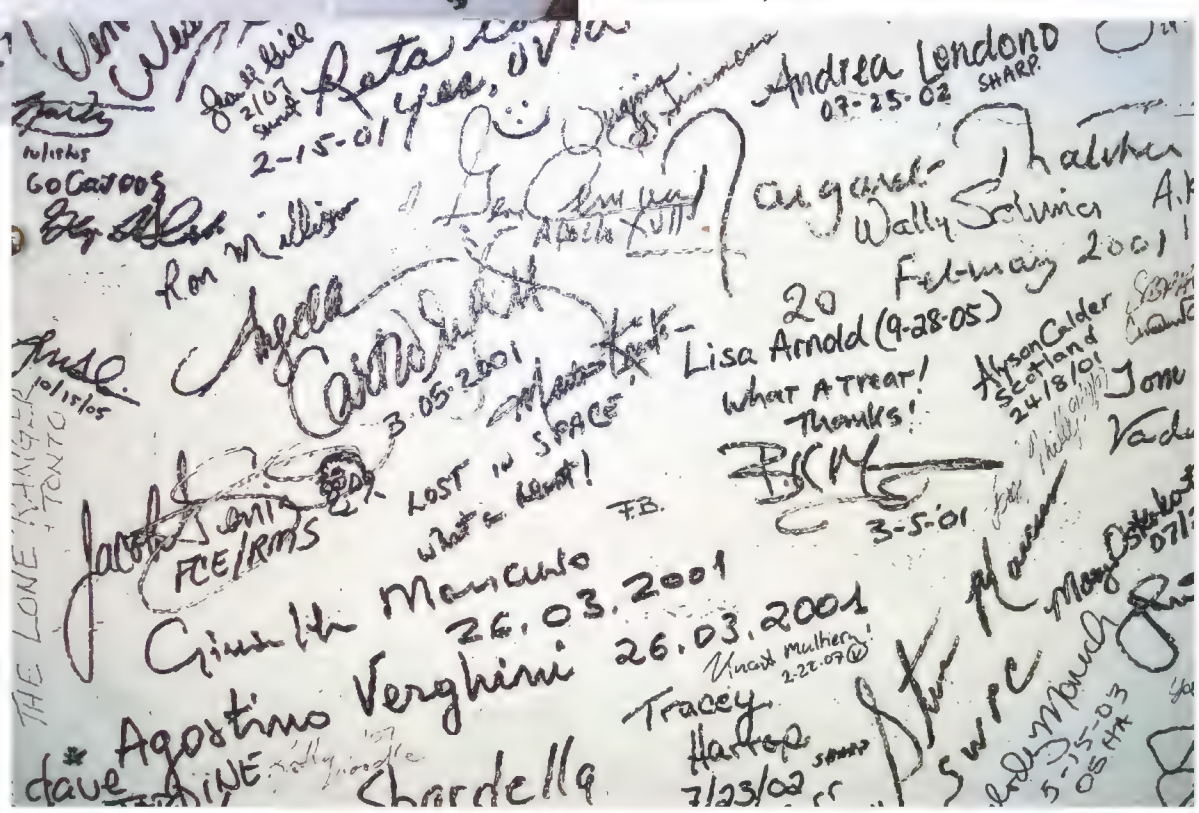
One day back in 1999, my late co-worker Dennis Bestwick hit on the idea of having a visitor use a marker pen to sign his name on the Bay III white room's pebble-finish wall. The idea caught on. We extended the practice to Bay II (and much later Bay I, whose display is still the smallest), and before long it was part of the routine: Get your tour, sign the wall. Sometimes no one could find a marker and the visitors used an ordinary pen; those signatures are now fading. Others have been obliterated by changes to the white rooms, like the addition of more power outlets.

The growing collection of autographs has been seen by only a few. Public tours through the Orbiter Processing Facility's bays are limited to the ground floors, where the white room interiors are not visible. And because of security concerns after 9/11, those tours have been curtailed.

Though our walls are not as moving as the Vietnam Veterans Memorial Wall, or as important as an airplane signed by thousands of assembly workers, we shuttle techs nonetheless wonder what will happen to this treasure when we recover the last shuttle mission in 2010. Let me be the first to call for the National Air and Space Museum to preserve these walls as part of a space shuttle exhibit when our aging tri-motor orbiters themselves become part of history.

RICHARD G. VAN TREUREN

The signatures of the lost crew of STS-107, *Columbia*, in the upper right of Bay II (left), have a special place in the hearts of the spacecraft operators: The crew members brought the mission sticker to put on the wall themselves.



In a few square inches of Bay II (right) are the autographs of Apollo 17's Eugene Cernan, the last man to walk on the moon; British Prime Minister Margaret Thatcher; Wally Schirra, the only astronaut to fly on Mercury, Gemini, and Apollo missions; and Angela Cartwright, Marta Kristen, and Bill Mumy – otherwise known as the "Lost in Space" Family Robinson. Nearby are signatures of New York City police and firefighter survivors of the 9/11 attacks, Apollo 13 commander James Lovell, and astronaut Eileen Collins' brother and sister.

RICHARD G. VAN TREUREN (3)

Music to Fly By

THE OFFICIAL AIR FORCE SONG was conceived in 1939, after *Liberty* magazine publicized a $1,000 prize for "a spirited, enduring musical composition" to give the Air Force predecessor, the Army Air Corps, a song of its own.

Entries poured in from across the nation, penned by widows, bureaucrats, mechanics, waitresses, prison inmates, soldiers, and retirees, but the results were disappointing. "We had received over 700 manuscripts and only a few were worth even taking to musical experts that we had decided to consult," lamented Mildred Yount, chair of the song selection committee and wife of Army Air Corps General Barton Yount. The winning song was not submitted until two days before the contest deadline, July 15, 1939.

If the entry proclaiming "Off we go into the wild blue yonder" hadn't turned up, today we might be humming a rendition of "Open Throttles." Or a plucky "Give 'er the Gun." Or "Crank 'er Up," written by an airplane mechanic.

"Eyes of Our Nation" showed potential, but fizzled by the second verse: "We're the eyes of the nation, scouting here and there. Our sky wagons at home in the clouds, with us none do compare. We're the boys of courage, a stout and fearless bunch. Let's sing a song in the choppy air waves as we do our stunts."

Perhaps a little too esoteric was the submission from a retired airman, "The Chandelle," named for a combat maneuver developed by a Frenchman in World War I. One composer with a plodding style wrote "The Airplanes Keep Winging Along." A mouthful came out of Bad Axe, Michigan: "For Greater Than the Eagle's Wings, Are Air Corps of the U.S.A."

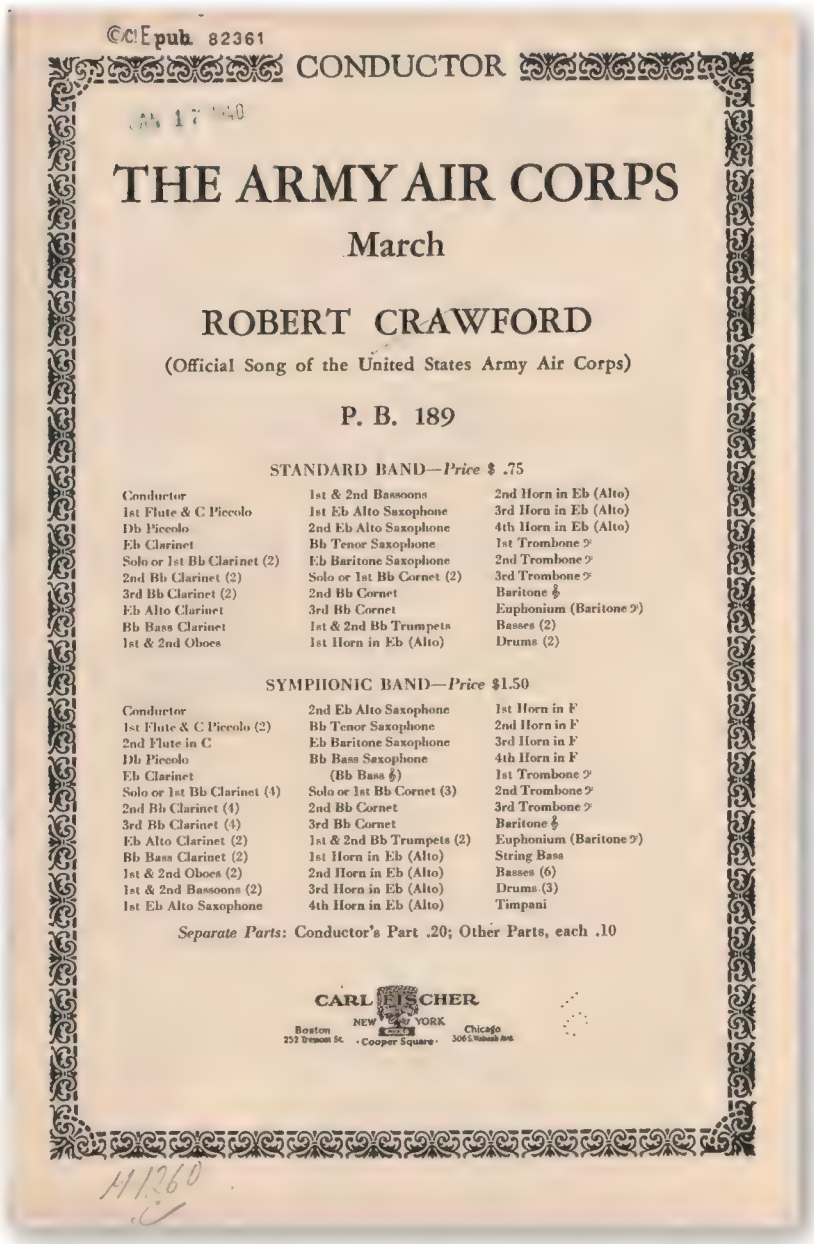
Destined for obsolescence was "Props and Wings." "Aero Rag" was stylish, but a touch too trendy. Several entries were previously published songs submitted by music publishers, among them "Flying High," "Men With Wings" (from a movie of the same name), and "Aces Up."

"Wings on High" came from youthful composer Meredith Willson, who went on to songwriting fame with *The Music Man.* Irving Berlin wrote a song at the Air Corps' request, but it wasn't chosen. It eventually aired in Moss Hart's *Winged Victory*, a play and movie.

A piano tuner in Oregon wrote to ask: Since the branch's name was the U.S. Army Air Corps, was "corps" pronounced singular or plural? Air Corps public relations man Ira Eaker, who would later be named deputy commander of the Army Air Forces, dutifully replied so that the tuner could get his rhyming right.

Song selection was the responsibility of a committee of Air Corps generals' wives with musical backgrounds, along with Colonel Edmond L. Gruber, composer of "The Caissons Go Rolling Along," who noted, "You can't force Army songs. When you find a song you will like, it will come from a young flyer, one who has the feel of flying in his bones and knows the thrill and the glamour of the Air Corps."

Gruber was right. The winning entry came from a professional musician known as the Flying Baritone, Robert Crawford, who flew his own airplane to performances (and became an Air Transport Command pilot during World War II). The committee voted almost unanimously for Crawford's song, but not his title, which was "What Do You Think of the Air Corps Now?" It was published as "The Army Air Corps" and later "The U.S. Air Force," after the branch became a separate service in 1947. Crawford himself sang the public debut at the 1939 National Air Races in Cleveland, Ohio. As a tribute to Crawford—and the Air Force—the all-Air Force crew of Apollo 15 took a sheet of the original score to the moon in 1971 aboard the lunar lander *Falcon.*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Solo or 1st Bb Clarinet (2)	Eb Baritone Saxophone	2nd Trombone 𝄢
2nd Bb Clarinet (2)	Solo or 1st Bb Cornet (2)	3rd Trombone 𝄢
3rd Bb Clarinet (2)	2nd Bb Cornet	Baritone 𝄞
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Air Racing 101

A COURSE IN HANDLING THE COURSE AT THE NATIONAL CHAMPIONSHIP AIR RACES.

LARRY LOWE

WHEN THE RENO AIR RACES STARTED in 1964, they were based on the premise that out in Nevada's high desert, where there was no one around to suffer collateral damage, all bets were off. If you came to race, you knew the risk and accepted the consequences. The traditional way to learn how to race was to simply strap into a race plane and go take a good look at the pylons. The bravado of self-education added to the ethos of the sport, but it took a toll on pilots and airplanes. In the first four decades Reno lost 15 pilots. After a particularly preventable fatality in 1994, racer Alan Preston went to operations director Bill Eck and revitalized a concept that had been discussed over the years. In 1998, when the Sport class debuted at the Reno Air Races, a school to learn to race airplanes debuted with it.

In June each year, the Reno Air Racing Association conducts a mini-camp of classroom instruction and on-course race training with the goal of introducing the rookie to the racing experience minus one key component: the pressure of a real race. It's the same course, the same capricious winds, and the same airplanes as race week. Push too hard, make an error in judgment, overlook a critical detail, and you can tear up an airplane—or worse. But the environment of the Pylon Racing Seminar allows rookies to make mistakes and learn from them.

All racers must attend the seminar unless they have competed in the same class within the past three years. Over the years, the original four classes—the Unlimiteds (mostly World War II fighters), Formula One homebuilts, small biplanes, and North American T-6 World War II trainers—have been augmented by jets and production kit-built sport aircraft like the composite-construction Lancairs and Glasairs. The Reno Air Races earned the title of world's fastest motor sport from the Unlimiteds, which hit speeds above 450 mph, but the Formula Ones (limited to 200-cubic-inch engines) and other classes are equally dangerous. A clear understanding of the race pilot's role in the complex schedule of a day of racing is what the seminar is designed to deliver, with a combination of Reno lore, repeated procedure drills, and practice emergencies. For $800 (and BYOA: bring your own airplane) and successful completion of a check ride, the aspiring pylon racer is certified to compete. Attitude control at the PRS is about the pilot, not the airplane. The instructors begin with a psychological indoctrination into the harsh realities of air racing.

"Your airplane does not love you."

Alan Preston draws a big square on the white board behind him, representing, he says, the operational limits of the modern racing airplane. He draws a smaller, lower square that overlaps that of the airplane only partially; it represents the bounds of the pilot's abilities. The modest intersection of the two, Preston tells the rookies, is all you have to work with to save your life if something goes wrong on the course.

That sobering conclusion is followed by an animated presentation by Tiger Destefani, a cotton farmer from Bakersfield, California, who won the Unlimited Gold six times in the modified P-51 *Strega*. When you "pop" the engine—Destefani's term for catastrophic failure—declare a mayday and follow these procedures: Radio the crash trucks if possible. Pull left up off the course toward the center of the airport, level off at best glide speed, and try to set up for runway 14. Get the landing gear down early and keep the airplane as high as you can as long as you can on the approach. Shoot for landing a third of the way down the runway, because when the propeller blades go flat from loss of oil pressure and the prop disc turns into a drag plate, you will come down a lot steeper than you thought possible.

The rookies are pilots with a wide range of aptitude, experience, and motives, from 20,000-hour airline pilots to weekend warriors with fairly new li-

BY LARRY LOWE

A trio of Sport class racers skim the high desert while instructor C.J. Stephens (in red shirt) points out the course to rookies (from left) Vince Walker, Rod Von Grote, and Michael Lloyd.

JAN PETERS

SCOTT GERMAIN

censes. After the initial mass briefing, they split up into their classes to get down to specifics. The Sport class retires to a classroom with Rick Vandam and C. J. Stephens, two senior check pilots.

Stephens and Vandam outline the pilot's responsibilities. The first is to take the safety of others into account—winning the race remains secondary to managing risk. Make the briefings on time or you'll be locked out. Observe strict radio discipline. Keep attention open for situational awareness—what Stephens calls heads-up flying. Be predictable. Keep your fellow racers in sight and stay within theirs.

After the first classroom session, rookies get an impromptu cautionary tale from auto parts manager Scott Alair, a racer back for his second seminar, who asserts, "They're really serious about the low flying. Last year I got put on probation."

Come afternoon, it's time to fly. Stephens is in a Glasair III, a single-engine composite type that is a frequent competitor in the Sport class. Three pilots assigned to him will train as a team.

Michael Lloyd, who gets the number-two slot, flying off Stephens' wing, is an investment banker and an ex-military pilot from the San Francisco Bay area. When he hired Stephens to help him ferry a newly acquired Glasair III home, Stephens pointed out that the airplane was fast enough to compete in the Sport class.

Rod Von Grote is attempting the impossible task of replacing Darryl Greenamyer, who is stepping down after dominating the Sport class with the same ease he dominated the Unlimited class in the 1960s. (Greenamyer still has the highest number of wins in the Unlimiteds: seven golds.) Von Grote will fly Greenamyer's airplane, a highly modified Lancair Super Legacy. Andy Chiavetta, the genius behind the modifications and the man Greenamyer describes as "the son I never had," can, in real time, look at a computer-synthesized display of the Lancair's cockpit and operate as flight engineer via radio, freeing Von Grote to find the pylons and avoid traffic.

Rounding out the flight is Tara Zaccagnino, a New Jersey instructor in corporate jets who has the least experience. She is on the end of the formation, where she'll have room to operate, and any mistakes she makes won't ripple through the flight. Senior check pilot and Sport class instructor Rick Vandam will join her in the cockpit.

Stephens takes his flight to the northwest of Reno-Stead Field to fly up and down a long valley, where the three rookies practice separating from and rejoining the formation. Lloyd's blue and silver Glasair slides predictably in and out of formation like a pendulum, the pilot executing the breaks and rejoins with a graceful and reassuring reliability. Von Grote, an airline pilot, has a tendency to overshoot his arrival as he gets used to the power response of his new propeller-driven environment. Zaccagnino, flying on the whiplash end of the formation, has her hands full anticipating the power required when the lead airplane begins a turn, and the drag needed to keep from overtaking the others when she arrives in formation. Midway through the session, a mechanical malfunction causes her to take the aircraft back to Stead Field.

Stephens calls for the two remaining members to fall into trail formation for the entry to the course. He takes the flight down to 200 feet and cruises one lap around the 8.48-mile Unlimited course before turning onto the smaller Sport course.

Race week consists of pre-flight maintenance, racing, and post-flight maintenance; repeat as necessary.

Scotty Germain steers toward a Sport course marker with an admonition ringing in his head: "Stay outside the pylons."

The reason for this simple orientation flight is obvious once you're up there: If you don't know exactly where to look, the brown telephone-pole pylons with the orange and white barrels at the top are nearly impossible to see against the mottled brown desert, even from 200 feet. A good racing pilot is projecting his line around the next pylon from the one he is about to pass, so a clear understanding of where the pylons actually are is vital.

After four laps in loose trail to establish the course, Stephens leads the two rookies to the "cool down," a circular track at 3,000 feet where an engine can unwind from race power and a pilot's consciousness can recover from the blur of the desert in preparation for landing.

Soon the rookies are rolling down Runway 26, transitioning from the "hot" side, near the interior of the course, to the "cold" side, where they can slow for turnoff and not be a hazard to a following racer who may have landed fast, or lost his brakes.

On Friday morning, the pilots assemble in the briefing room. Stephens briefs his group of three pilots on the mission profile: a rejoin to formation after takeoff, a practice start, some laps. At some random time, Stephens will call for an engine failure, and that pilot must pull the power back to idle and find a runway.

On this flight they are taking the course at 150 feet. After one lap, Stephens climbs to observe from above. When he calls for the simulated engine-out, Lloyd climbs to an altitude from which he can S-turn over to runway 14, making his emergency landing approach easily.

Von Grote isn't as lucky. His approach ends up a bit short of runway 14. Had this been a real emergency, he probably would have walked away, but the airplane would likely have slid into the desert.

Now Stephens has each racer pull out of formation and roll the airplane inverted, hang in the harness a beat, then roll right side up. This exercise introduces the pilots to the wake turbulence effects they would experience if they tangled with the vortices streaming off the wingtips of the airplanes in front of them.

After lunch, Stephens takes the class out for passing practice. For this session the group is joined by Vince Walker, a FedEx DC-10 pilot from Colorado who has pressed his Extra 300L into service as a trainer because the Lancair he is building is not ready to fly. The Extra is designed for maneuvering, not speed; Walker will strain to keep up with the flight.

Once the rookies are spread out, Stephens pulls the power back and eases out a few degrees of flap to slow to 150 mph, which allows Lloyd to attempt a pass.

Lloyd slowly approaches Stephens' right wing. Stephens holds the lead Glasair in a smooth line, and eventually Lloyd's Glasair disappears under the trailing edge of the right wing. Now Lloyd's aircraft is close to the instructor, but not visible to him. Five or six seconds later, the nose of Lloyd's airplane should have slid out from under the leading edge of the right wing, but it has not appeared. Tension rises in the cockpit of Stephens' aircraft: There is a racer close but out of sight and behaving unpredictably.

Stephens thinks he knows what happened. After several seconds, he rolls the Glasair into a steep bank at the apex of a pylon turn. Sure enough, Lloyd has crossed under and in front of Stephens and is focused on his path, having assumed Stephens' airplane is no longer a factor. It's not, of course, unless Lloyd has an emergency and pops up off the course without thinking, but a pilot in Stephens' position would have no idea where Lloyd's airplane was after it disappeared under the right wing. It's an honest mistake of aggression.

Von Grote pushes up the power on the Super Legacy, announces he is starting to overtake on the right, and flies smoothly past Stephens, establishing a several-airplane-length margin before sliding into the line and claiming the lead.

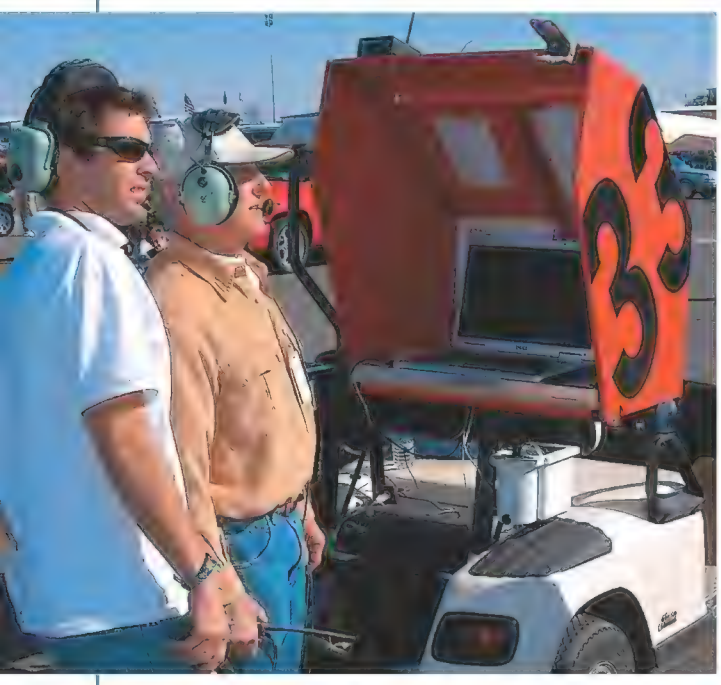
Stephens cuts across the course to settle in front of Walker's Extra. Walker gives the Extra full throttle and slowly crawls into close formation behind Stephens' airplane. But the Extra just doesn't have the requisite five knots to overtake the Glasair. After a lap and a half of close trail, Stephens abandons the exercise. He calls the class off the course to cool down.

David Sterling, an airline pilot who built his own Lancair and implausibly claims he came to Reno because he has 20,000 hours and has never done anything exciting in an airplane, is about to

Vince Walker escorts his just-completed Lancair Legacy to the runup area. Other racers pitched in to help him with last-minute preparations.

JAN PETERS

DAVID PETERS



LEFT: DAVID PETERS; RIGHT: VICTOR ARCHER

A computer-synthesized display enabled Darryl Greenamyer (above, at right) and Andy Chiavetta to monitor Rod Von Grote's instrument panel in flight. The super-sleek NXT Sport class racer (right) is a study in aerodynamics.

join up with a different formation of three. He's well away from the field when he hears a call on the radio for his race number to execute the engine-out procedure. Sterling fails to realize that the call is for Jet class racers currently on the course. He dives toward the airport with the throttle back, executing an approach in the path of a flight of L-39 jets. It's an embarrassing miscue that will take some living down, but everyone gets a lesson in maintaining the bigger picture.

Another infraction was strike two for Scott Alair. Despite repeated warnings from instructors, Alair elected to take his airplane down too low on the course and—for the second time in as many years—has been sent home on probation. It's safer, Alair claims, if he gets the airplane down below the tops of the pylons, because he has motocross race experience and the view down low enables him to transfer that experience to air racing. When asked if he would want a pilot he followed at arm's length to pull the same stunt on him, Alair reflects for a moment and decides no, because that pilot, 31,000-hour veteran Ernie Sutter, is, in Alair's judgment, "not as good a pilot as I am."

On the last day of the seminar, each aircraft class is given an extended single session on the course. As many pilots as care to can fly in a simulated race. The combined Sport class flights make an impressive gaggle of 10 as they come down the start. Stephens casts a watchful eye on the rookies from the ramp.

After 10 laps—more than the number in a real race—Lloyd finds himself in a tight formation of racers when keeping track of everything overwhelms him. Wisely, Lloyd elects to pull up and enter the cool-down area.

After a few laps, he's sufficiently recovered the proper frame of mind and makes a diving reentry at the home pylon. The decision to pull out rather than continue in what was becoming, for him, at his level, an overwhelming experience is the critical mark of self-awareness—exactly what the instructors hope for.

Two months later, the graduates show up at Reno for the 2006 National Championship Air Races. Michael Lloyd arrives with the Glasair III in perfect condition, sporting race number 21 on the side and "Miss Conduct" on the cowling. He has enlisted a support crew and is keeping the dangers and rewards of air racing in perspective. On Wednesday of race week, Lloyd becomes the first rookie of the class of 2006 to race at Reno, taking third place in Heat 1-C at an average of 261.712 mph. He can now add "race pilot" to his aeronautical résumé.

Vince Walker has barely finished his homebuilt Lancair Legacy in time. The airframe is still in epoxy primer. Self-sufficient to a fault, he works alone, preparing the airframe for racing when he should be focused on preparing himself. As race day approaches he's still making significant adjustments. Finally, members of Andy Chiavetta's crew give him a hand finishing the preparations.

Heat 1-B takes place under overcast skies on a blustery Thursday morning. This race has the largest number of rookies, including Walker and David Sterling, who says he's prepared for what is about to unfold: "Without PRS, I'd be a hazard to navigation" on the course.

The Lancair IV pace airplane, flown by Lancair factory pilot Timothy Ong and carrying pace pilot Rick Vandam, launches down runway 26, cuts to the north, and begins the turn to allow the racers to join up. First in is Craig Sherman in Race 19, a turbocharged Glasair. Sport class president Mike Jones slips his Glasair smoothly into the number-two position. Suddenly a white and orange blur slides under the gathering flight, racks into a steep bank on arrival in formation to kill the excessive overtake speed, and parks in the number-four spot. It's an unnecessarily flamboyant arrival for Scott Alair, in Race 77. He passed his re-certification check ride just in time to enter the competition.

Eventually the remaining racers assemble in a long string off Vandam's right wing and are headed behind Peavine Mountain for entry onto the course. Amid the turbulence, the racers are managing a stable separation. As speed increases on the final run down the chute, Heat 1-B forms a single line abreast. Just short of the approach end of runway 26, Ong tells

PRS-certified pilots only, please. It takes practice to fly this close, this fast. Number 77, right, learned the hard way that he had the wrong stuff.

DAVID PETERS

Sport class pilots, all of whom have earned a PRS patch, gather on the flightline for the critical pre-race briefing.

them they have a race and pulls the Lancair IV up abruptly so he and Vandam can evaluate the critical run from the start to the number-two pylon. It looks clean.

Eight minutes later, after Craig Sherman flies inside, instead of outside, a pylon, Mike Jones wins. Ernie Sutter edges out Vince Walker by 0.4 mph, with both of them a fraction short of 290. In his first race, David Sterling takes last place.

Rod Von Grote takes off in the gold race for Sport class. On an early lap, he radios to his crew that he thinks John Parker, in his Thunder Mustang, has cut a pylon. Darryl Greenamyer advises Von Grote to ease in behind Parker and stay there. Von Grote blisters past the home pylon behind Parker but ends up winning—when Parker is disqualified—by doing just what C.J. Stephens advised back in July: Keep your head up and know what is going on elsewhere on the course.

There are no more rookies now, only race pilots.

Three fatalities incurred during race week 2007 would cause some to wonder if there is any foolproof way to make air racing safer. The PRS at least sets high standards and puts on notice pilots who don't meet them. Before the 2006 races are finished, Scott Alair will make one mistake too many. Coming off the race start, he cuts under and across the four aircraft to his left, attempting to gain a minor tactical advantage, which causes Ernie Sutter to take evasive action. The executive committee determines that Alair is a hazard and permanently bans him from racing at Reno in any class.

JAN PETERS

What the Red Baron Never Knew

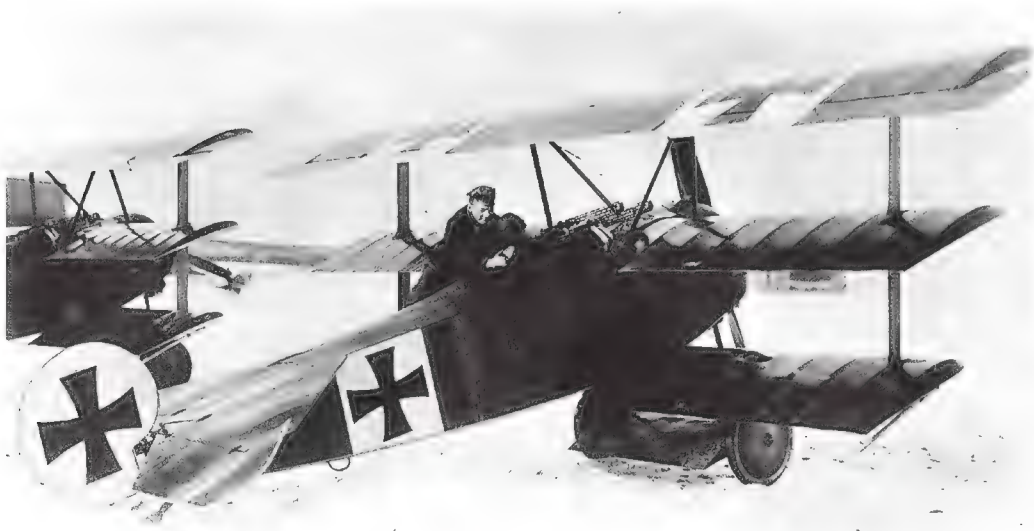
Computer analysis of World War I aircraft shows precisely why some were deadly and others, death traps.

BY PETER GARRISON

THE "FLYING MACHINE," born only a decade before World War I, matured swiftly during its teenage years. By the end of the Great War, aviation had already adopted nearly every major feature that would characterize military and civil airplanes for the next three decades. Cecil Lewis, a British fighter pilot whose memoir *Sagittarius Rising* is a classic of the era, wrote, "Every new machine was an experiment, obsolete in the eyes of the designer before it was completed, so feverishly and rapidly did knowledge progress." No other period in the history of aviation has seen such rapid evolution.

Most of the improvements emerged from trial and error. But what if designers during the first World War had had the tools for simulation and analysis that are available today? Many of the errors would have been avoided had the firms of Fokker, Sopwith, Nieuport, and the rest had a few desktop computers.

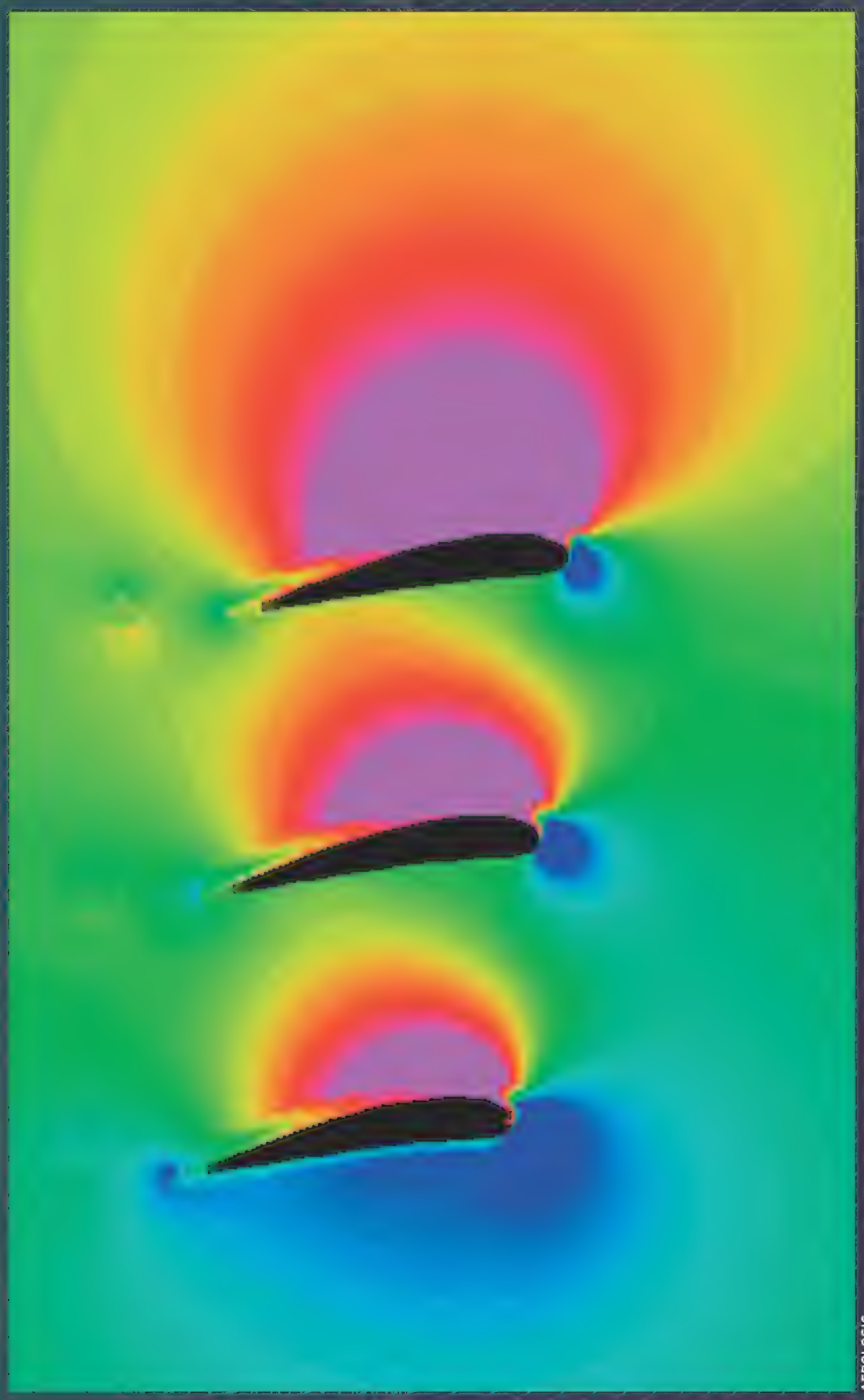
Baron Manfred von Richthofen's Fokker Dr.I had a good reputation, but a closer look proves the middle wing was nearly worthless.



NASM (SI NEG. #00119750)

The first error, made with the first airplane, was soon corrected. When Wilbur Wright took the *Flyer* on a sales tour of Europe in 1908, the virtuosity and self-assurance of his daily demonstrations stirred up a fever of renewed aviation activity among the Europeans. But the very next year, Frenchman Louis Blériot flew across the English Channel in an airplane whose configuration looked nothing at all like the Wrights'. The world abandoned the Wrights' design, an unstable canard biplane with pusher propellers and a central engine, promptly and without regret. Blériot's design—single wing, direct-drive engine in front, tail in back—foretold all the best design conventions of the next half-century.

The airplane that crossed the channel was Blériot's 11th creation, and none of the previous 10 had looked much like it or, for that matter, like one another. While the Wrights had painstakingly refined one idea through study and experiment, Blériot seems to have randomly caromed from one design to the next, inspired by a series of unconnected ideas, until he chanced upon one that worked. Now if he had



AEROLOGIC

Fokker's Inefficient Triplane

When you place one wing above another, each modifies the pressure field of the other. In the case of a biplane, the low pressure above the lower wing is partly canceled by the higher pressure below the upper wing.

In other words, you end up getting less lift from the lower wing. But drag, which is largely due to the friction of air against the wing's surface, remains unchanged. Overall, the efficiency—the ratio of lift to drag—of the lift-producing system is lower.

A computer simulation makes the interference problem visible. We see the three wings of the Fokker Triplane at an angle of attack of 10 degrees, which corresponds to a steep climb or a tight turn. The colors indicate different air pressures: Magenta and red are low; green, neutral; blue, high.

What is most striking is that the middle wing's contribution is very meager. Its high and low pressures are partially canceled by the wings above and below it.

A monoplane wing, in contrast, would combine the high pressure below the Triplane's bottom wing with the low pressure above its top wing, yielding maximum lift for minimum drag.

had a PC... An elementary analysis calculating pressure distributions could perhaps have saved him the trouble of the first 10 discarded designs.

The first great fighter of World War I was essentially an improved copy of the Blériot XI—a sportsman's airplane equipped with a gun. Called the Eindecker—the name means "monoplane"—it was designed by Anthony Fokker, a young Dutch engineer, pilot, and entrepreneur living in Germany. The Eindecker had an "interrupter" system, enabling its fixed, forward-pointing machine gun to fire through the propeller without chopping the blades off. (One of the mysteries of the history of technology is the inability of the British and French, who could build both engines and machine guns, to quickly contrive a satisfactory way to synchronize them.)

Mainly because of its superior armament, the Eindecker ruled the skies above the trenches during the first year of the air war. Newspapers on the Allied side spoke of the "Fokker Scourge." That such a rudimentary and wayward machine could be the dominant fighter of its era only shows how primitive aviation still was at the start of the war.

By 1916, the Allies were producing fighters superior to the Eindecker, and the Fokker Scourge came to an end. The new formula, exemplified by the Allies' various Sopwith and Nieuport models, was a wire-braced biplane with thin, essen-

The D.VIII Future Shock

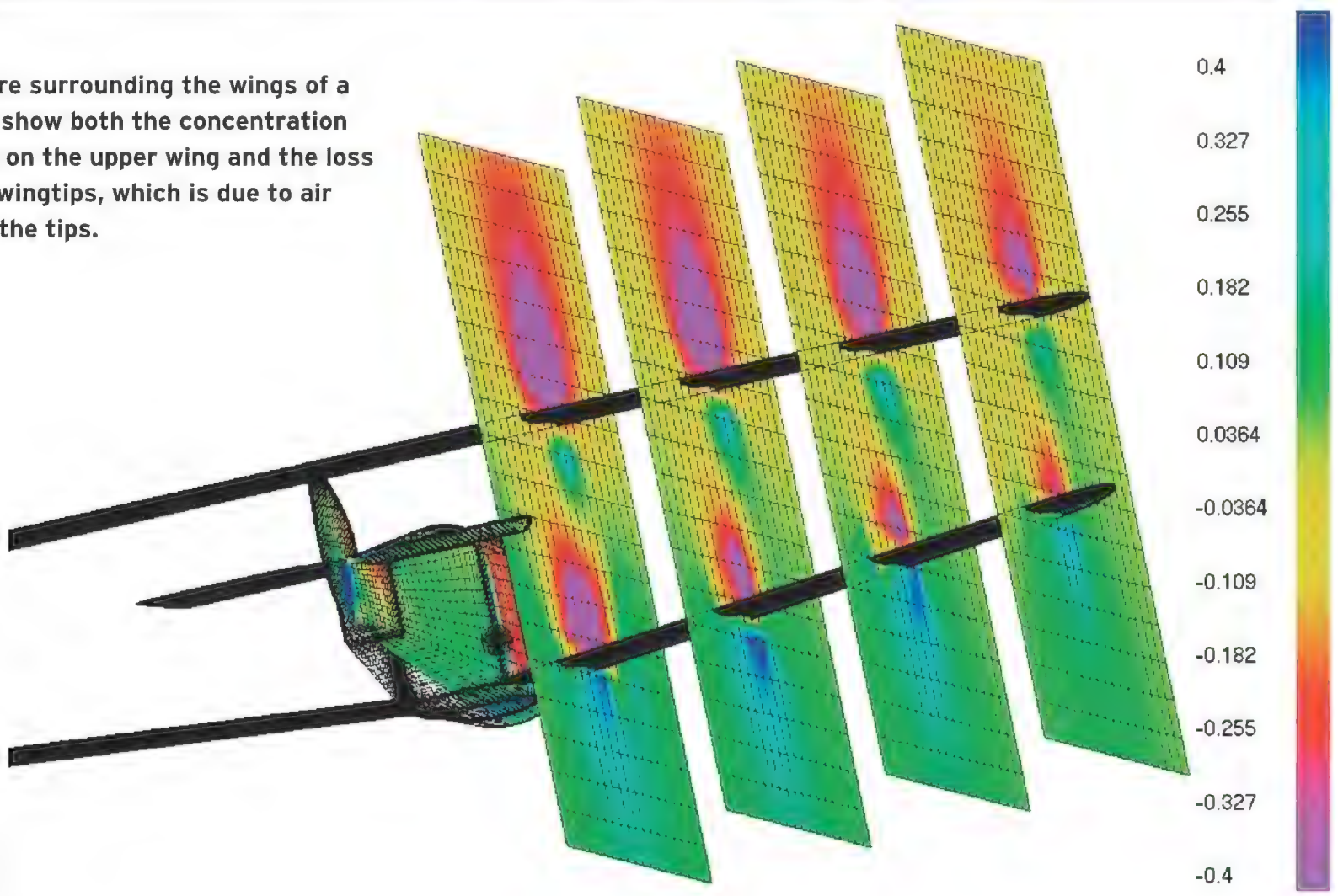
From an aerodynamic standpoint, the most prophetic design of the war was Fokker's D.VIII, which was, against the general trend, light, nimble, and rotary powered.

The D.VIII was a parasol monoplane, a single wing with fuselage suspended from it on struts. It was the wing that set the D.VIII apart from its contemporaries.

Gracefully tapered in chord and thickness, completely sheathed in smooth plywood and equipped with narrow, sealed ailerons, the wing was sophisticated enough that it could have been designed in 1940 instead of 1918.

The boxy fuselage looked a lot like the old Eindecker's, but the D.VIII's marvelous wing eclipsed all its other faults; it might as well have been a time traveler's gift from the future.

Without computer analysis, wing strength sometimes had to be proved by more conventional methods.



Plots of pressure surrounding the wings of a Sopwith Camel show both the concentration of low pressure on the upper wing and the loss of lift near the wingtips, which is due to air spilling around the tips.

AEROLOGIC

tially rectangular wings. The superior rigidity of the bridge-like wing structure enabled higher speeds and more agility, great advancements for dogfighting.

Then British builder Thomas Sopwith produced a triplane. To enhance pilot visibility, he narrowed the wing's chord—the distance from leading to trailing edge—and, intending to replace wing area lost, added a third skinny wing. The Sopwith Triplane was a pleasant-flying, stable, and even warm and cozy airplane—not a small concern when pilots prowled at 18,000 feet. A brief but intense international flurry of triplane designing followed. However, the only model to reach the front was the Fokker Dr.I. The "Dr" stood for Dreidecker, or triplane.

Even though Baron Manfred von Richthofen scored a number of victories in this triplane, three wings was a bad idea (see "Fokker's Inefficient Triplane," p. 29). No doubt it seemed to many that more wing area would mean more lift, and therefore a better rate of climb, but the rate is determined by weight, power, and wingspan.

An aerodynamicist at the Massachusetts Institute of Technology, Jerome Hunsaker, saw the fallacy of the triplane arrangement and in 1916 published a critique of it. According to Leon Bennett, whose book *Three Wings for the Red Baron* explores the triplane phenomenon at length, a German translation of Hunsaker's work "did much to dampen triplane hopes." Nevertheless, hundreds of Fokker Triplanes were built, and a reputation of high performance—especially rapid climb—grew up around them. Von Richthofen, their staunchest advocate, claimed that his triplane could "climb like a monkey and maneuver like a devil."

Modern tests and theory agree about the devil, but not about the monkey. If the Dr.I could, in fact, outclimb the Sopwith Camel biplane that it often fought, it was not because it had an extra wing but, Bennett suggests, because its propellers were pitched to de-

OPPOSITE: NASM (SI NEG. #98-15116)

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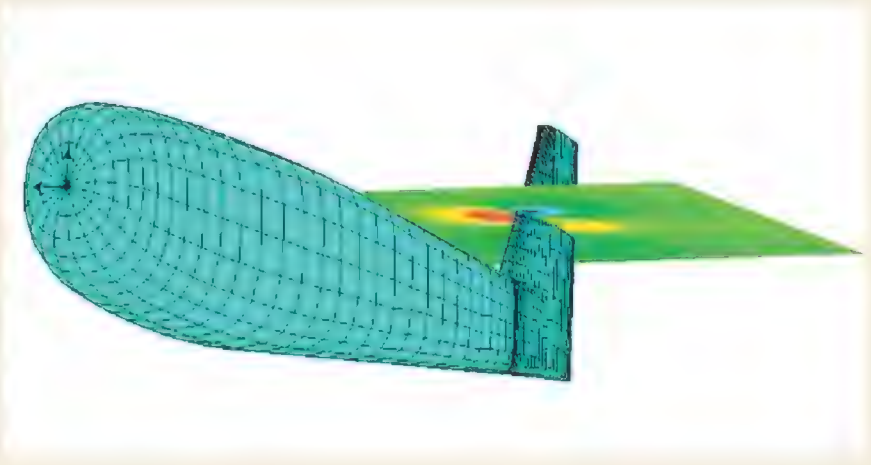

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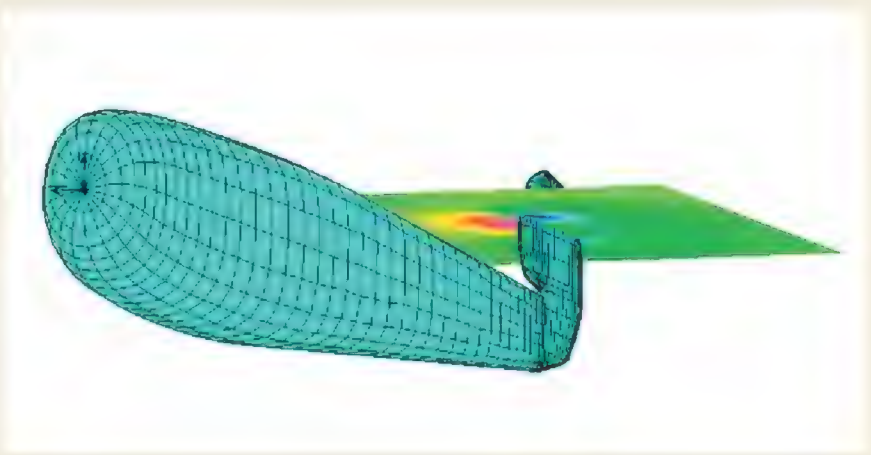


Fins and Rudders

Rudders evolved during the war and the behavior of airplanes changed along with them. Early fighters, like the Fokker Eindecker, had one-piece rudders resembling those of small boats. Balanced by a portion projecting ahead of the hinge line, they would stay put in any position. The pilot had to constantly adjust the rudder in order to control the airplane, which had no tendency to point in the direction of the oncoming air.

Then designers added fixed fins, most likely at first to strengthen the rudder mounting by placing the hinges farther from one another. The fixed fin, however, changed the behavior of the airplane, which now tended to return to point in its original direction rather than skid at an angle to the airflow. Pilots came to prefer this type of stability, which both made airplanes easier to manage and increased their speed by keeping the fuselage well-streamlined. Good stability required a large fin, however, while maneuverability for fighting demanded a corresponding enlarged rudder. By late in the war, airplanes like the British SE.5 had fins and rudders of modern-looking proportions.

As the pressure maps of both types show, however, the older, much smaller rudder was able to deliver the same amount of maneuvering power as its later, bigger counterpart, because it did not have to overcome the resistance of a large fixed fin.

The view of this captured Fokker D.VII (top left), idling at Bolling Field in Washington, D.C., after the war, showcases the fixed vertical fin. The analysis above shows that the switch to fin and rudder had almost no effect on maneuverability.

liver maximum power at climbing rather than cruising speed. Fokker Triplanes did in fact lack in top speed what they possessed in climb.

The Fokker Triplane actually did exhibit one extremely important design innovation, but it wasn't the three-wing arrangement. It was the thick cantilever wings. Unlike most airplanes of its era, the Dr.I needed no struts or bracing wires to hold it together, as Fokker was fond of demonstrating by having a couple dozen of his shop workers pose on a wing.

The idea of the thick cantilever wing seems to have originated not with Fokker, however, but with German Hugo Junkers, who came into his own as a manufacturer only after the war. Junkers' all-metal monoplanes, a decade ahead of their time, had no external bracing at all.

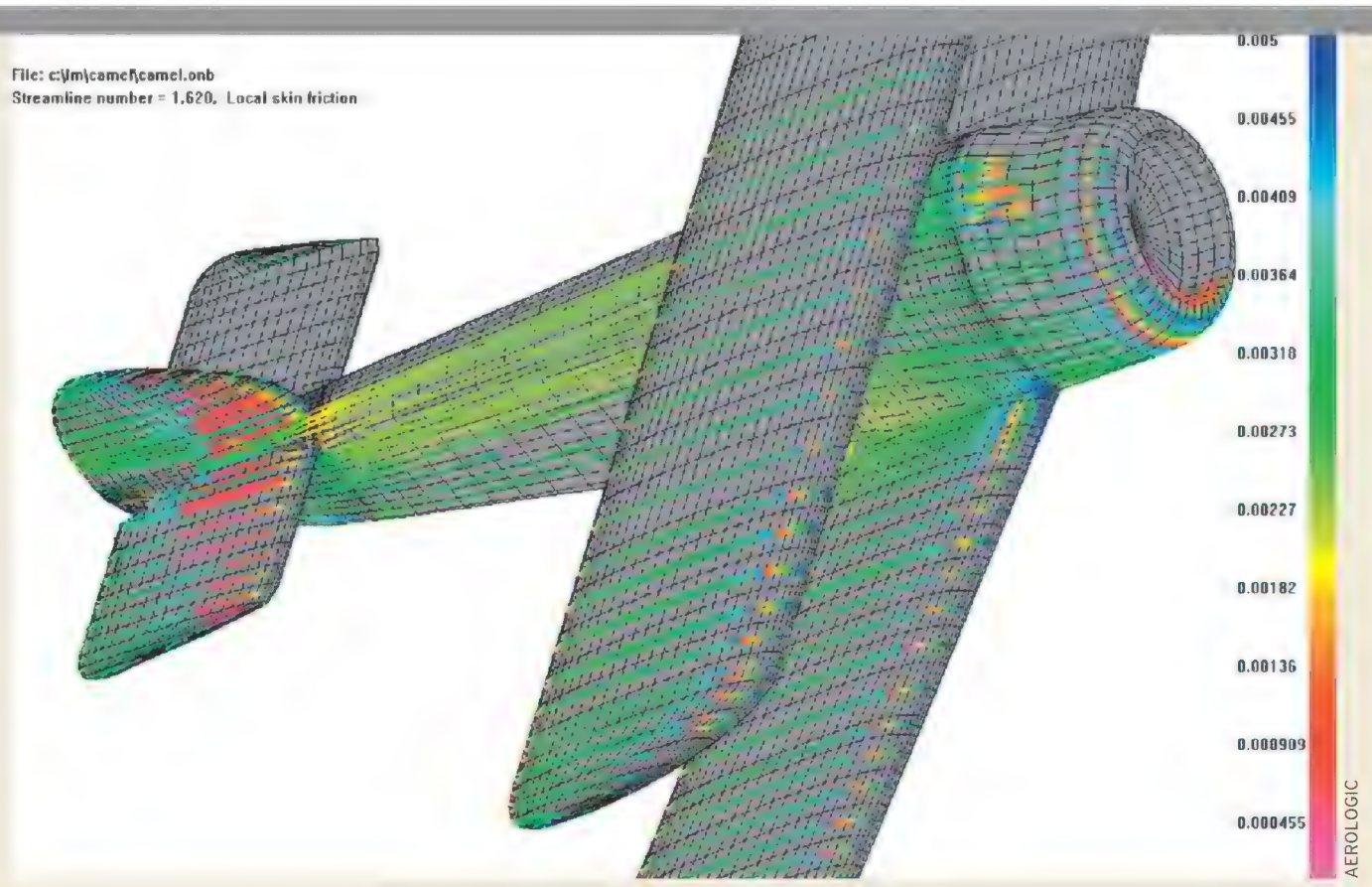
It isn't clear how Junkers came to the realization, around 1915, that a thick wing would not produce any more drag than a thin one. It was a counterintuitive notion; throughout the war, the British persisted in believing that thick-wing airplanes must be naturally inefficient.

Thick airfoils had a great advantage besides the structural one. Compared with thin wings, thick wings could produce more lift, by about 25 percent, because the gentle roundness of the leading edges helped air follow the curvature of the airfoil and not break away. The added lift did not affect climb rate, but it improved maneuverability, because the space within which an airplane can turn is determined by its maximum lift.

Sopwith Camel: Friction Is a Drag

Computers have trouble resolving the drag contributions, often very significant, of small protrusions, surface roughness, and flow through an airplane's interior.

What the computer can do very well, however, is compare measurements of the air resistance that different shapes create, and identify areas contributing drag. That capability, useful only when the overall shape of the aircraft is smooth, has been particularly useful in airfoil design.



This image of the Sopwith Camel is covered with lines, called "on-body streamlines," which show the paths that air follows over the body. The rainbow colors of the streamlines, in this case, indicate the amount of friction present, which is a function both of the airplane's shape and of the gradual thickening of the boundary layer of air that the airplane pulls along with it. Integrating the friction at thousands of points, the computer can total up the drag due to surface area and shape—which, in the case of the Camel, is pretty high.

Reducing drag is partly a matter of modifying shape and surface smoothness, and largely a matter of changing size. Engines, landing gears, guns, open cockpits, and structural bracing took early airplanes far from a streamline shape.

NASM (SI NEG. #85-11029)

Pilots of the Sopwith Camel complained that the engine, guns, fuel tank, and pilot were clustered too close. They didn't know the airplane's very shape generated drag that hampered its performance.

Dead Men Fought Fair

As the war went on, fighter tactics changed. The German ace Oswald Boelcke established a set of rules for aerial combat, emphasizing the importance of surprise, which influenced both sides. Dogfights were for rookies and dead men. Aerial free-for-alls risked collisions and defied any kind of complex tactical planning.

Aces preferred safer means—namely, sneaking up on an unsuspecting reconnaissance airplane from behind and above—and that maneuver required being faster than the opponent. By the end of the war, fighters had grown heavier and more powerful, both because of a fighting style that put more emphasis on surprise diving attacks and because of a recognition that beefier structures were needed to give pilots the confidence to maneuver. Fighters like the Fokker D.VII and the French SPAD were larger and heavier than their predecessors, and could dive at high speeds without coming apart.

NASM (SI NEG. #77-54)

A pair of German D.VIIs hunt for prey. With 160-horsepower engines and a fuselage of steel tubing, they could survive the rigors of aerial combat.

The Nieuport's Flimsy Wings

Throughout the war, both sides experienced intermittent problems with the wings' leading edges. In the course of violent maneuvering or in a high-speed dive, an airplane would, from time to time, shed the upper skin of a wing, the leading edge, or, occasionally, the entire wing.

The reason for these failures became clear after the war, when the National Advisory Committee for Aeronautics, the predecessor of NASA, conducted tests in the 1920s showing that in a sudden pull-up, the negative pressures at the leading edge could be more than five times greater than the impact pressure of the oncoming air. At 150 mph—regularly attained while diving, either to attack or to escape—the impact pressure is more than 56 pounds per square foot, so while the aircraft was rounding out of a dive, every single square foot of the leading edge of a wing might experience a pull of 300 pounds.

Small wonder that failures occurred, particularly in what U.S. World War I ace Eddie Rickenbacker called the "flimsy Nieuports," whose wings had their main structural members placed quite far behind the leading edge.

Similar problems occurred with ailerons. In order to make it easier for pilots to maneuver, designers extended ailerons beyond the wingtip and ahead of the hinge line. Air pressing on the portion of the control surface ahead of the hinge reduced the force needed to deflect the aileron, but if the extension was too long, the aileron became overbalanced and hard to manage, or the overhung portion could simply break.

Triplanes could also fly in a very nose-high attitude, because the thick wing kept producing lift at angles at which the sharp-edged wings of Allied fighters had already given up. A U.S. pilot, James Hall, wrote of the Fokkers' "trick of standing on their tails beneath one" with guns firing upward.

After von Richthofen's death in 1918, another fighter, now considered the best of the war, quickly supplanted the Triplane: the Fokker D.VII. The D.VII had many assets, not least its Mercedes engine and uncluttered design. It was a sesquiplane, with a lower wing smaller than the upper.

Both sides conducted wind tunnel work during the war, but much of it was misdirected. A lot of effort was dedicated to determining the amount of camber, or curvature, a thin airfoil needed to produce the most lift. The correct answer was that camber did not matter as much as a thick, well-rounded leading edge; a highly cambered thin airfoil might produce more lift than a less cambered one, but it also produced more drag. Only the thick airfoil offered the best of both worlds.

Biplane fighters were still being built well into the 1930s, but the all-metal, low-wing monoplane, the type pioneered by Hugo Junkers, would dominate World War II. As a computer would show, a simple, uncluttered shape provides a total drag much less than that of a D.VII half the size. A suitable computer would have colored Fokker, who died in 1939, green with envy.

Mr. B's Big

FLYING INTO LAS VEGAS on a westbound airliner, I gaze down at the casinos along the famous Strip, miles long, glowing in the night. It occurs to me that the city where Robert T. Bigelow—owner of the first privately held real estate in space—lives and works is itself a kind of satellite outpost, surrounded by harsh, empty desert. It's a fitting spot from which to control a pair of mini-space stations, Genesis I and II, launched in July 2006 and June 2007. The van-size modules are currently orbiting Earth, with daily operations run out of Bigelow Aerospace's mission control in north Las Vegas. Cost so far: under $100 million.

"If a few years ago anyone in the space industry told you they could develop, launch, and control two new satellites for less than $1 billion or $2 billion—let alone under $100 million—they'd be stringing you along," says former Bigelow consultant and NASA chief of staff Courtney Stadd. "But Bigelow has done it."

Having pledged five times that much—more than half his net worth—to build inflatable space habitats using technology pioneered, then abandoned, by NASA, Bigelow, with a company of roughly 125 employees, is aiming even higher. His goal is to send people to a larger, habitable module called Sundancer by 2010. By 2012, he hopes to place a full-size, 330-cubic-meter (11,700-cubic-foot) module, the BA 330, in orbit, with more to follow later.

For a company that's barely eight years old, it's an audacious plan, and I've come to ask the reclusive real estate mogul, who rarely grants interviews, how things are going. (Employees refer to him as Mr. Bigelow; those who work with him closely call him Mr. B.)

As I drive up to the Bigelow Aerospace facility, 10 miles north of the Strip, another famous Las Vegas recluse and aerospace pioneer, Howard Hughes, is on my mind. Maybe there's something about this place that breeds mavericks willing to buck conventional thinking in pursuit of grand engineering projects.

Set back on a 50-acre lot in a mixed residential and commercial neighborhood, surrounded by a razor wire fence, sit two large industrial buildings snuggled into a ridge. From a distance, a large white communications sphere on the ridge and twin radio towers are all that mark this as a space facility.

After being cleared through security (manned by guards with 9-mm pistols), I'm escorted into Building A—the huge assembly and integration area. I'm immediately disappointed. There's nothing much to see except for a few half-molds and a support platform. Then it dawns on me: Bigelow's first two spacecraft have left the building. They're in orbit.

In the weeks following the Genesis II launch, though, the company had said almost nothing about the spacecraft's health. This is private spaceflight, and it is just that—private. The module was said to have 22 interior and exterior cameras, improved versions of the ones on Genesis I, but the high-resolution images had not been released. In early August, a month before my visit, a cryptic statement from Bigelow posted on the company's cluttered Web site hinted at difficulties. Band-

Starting small: Genesis I (seen in orbit against a crescent Earth) has just 400 cubic feet of usable volume. The space shuttle is nearly six times as roomy.

ROBERT BIGELOW HAS PUT TWO MINI-SPACE STATIONS IN

BIGELOW AEROSPACE, INC. (2)

ORBIT. NOW COMES THE HARD PART. BY GEOFFREY LITTLE

Plan

width and downlink time were being reserved for command and control of the vehicle, not photos and videos. Perhaps all was not well with Genesis II.

Before the launch, a campaign called "Fly Your Stuff" had drawn a lot of attention. For $295 each, about 200 customers had sent tiny payloads (smaller than golf balls) into space to watch them, via interior cameras, float around the spacecraft cabin. Most people sent photos, but some sent personal mementos—a 1/52-scale race car, interlocking wedding bands, even a little wooden duck—that could be seen in the grainy but recognizable images beamed to Earth and displayed on the Web site. (Bigelow had promised that if in 90 days you didn't get a clear shot of your object, your money would be refunded.) One participant said on his blog, "It was neat seeing Mom floating in space. Dad would have been amazed."

While these and other pictures (including a video composite of Earth and photos projected on the exterior of the spacecraft) had come down from Genesis II, the number of high-resolution images was disappointingly low. Other experiments announced prior to launch had gone missing entirely. One, called Biobox, was to carry three species of insects. Another, a bingo game with air-driven ping pong balls, was to demonstrate on-orbit actuators and communication while providing entertainment for Web site visitors. Since launch, there had been no sign of the bugs or the bingo.

Inside Building A, I follow a guard up two flights of metal stairs, where a door opens onto a conference room overlooking mission control. There, a lone controller sits at one of six kidney-shaped desks, facing a huge wall of video displays that chart the orbits of both Genesis satellites. Captured camera images and tracking data stream across the screens—Apogee: 560 km; Inclination: 64.5°. Temperatures inside the modules range from 40 to 90 degrees Fahrenheit. All systems show nominal. At an altitude of 350 miles (75 miles higher than the International Space Station), the 2,800-pound satellites will orbit for seven to 10 years before reentering Earth's atmosphere.

I watch for several minutes. It's a lovely, hypnotic sight.

Mr. Bigelow breaks my reverie. He greets me cordially and ushers me into his modest-sized office, just off the conference room. It's decorated with plaques and a close-up portrait of himself with Buzz Aldrin. One interior window overlooks the shop floor, and the other looks onto mission control. Behind his desk sit two computer monitors, both dark; for many years Bigelow eschewed computers and e-mail entirely.

Today he's casual, wearing crisply pressed beige slacks and a short-sleeve dress shirt embroidered with a Bigelow Aerospace logo. A tall, trim, 63-year-old with a full head of silvery-black hair, Bigelow is well-coiffed, and his smile is relaxed under a full mustache.

"I spend about 40 percent of my time here," he says as we settle into two side chairs. The rest he spends at the headquarters of Bigelow Management, close to the downtown airport. From there he runs his hotel and real estate business and other ventures.

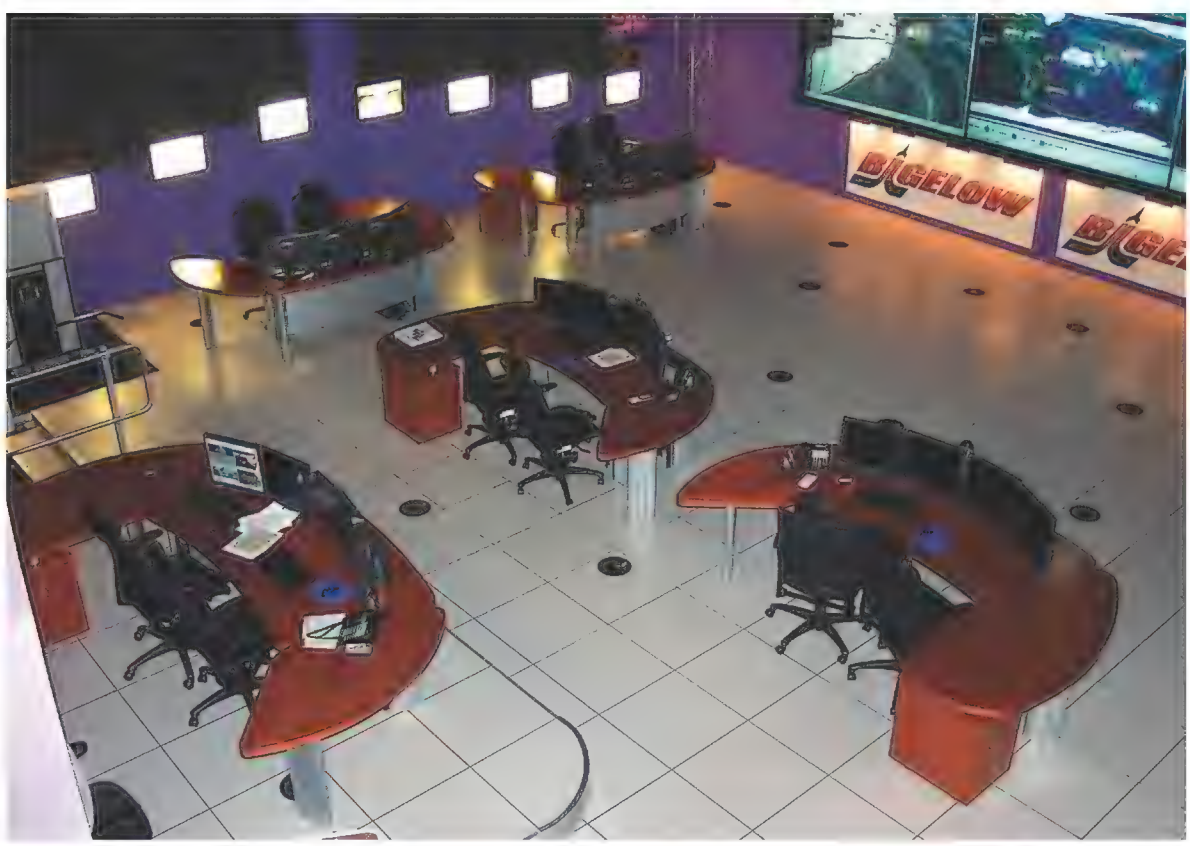
By his own estimate, Bigelow's fortune stands somewhere south of a billion dollars; he's never been on the *Forbes* 400 richest people list, which this year started at a billion. He's said repeatedly that he can meet his $500 million commitment to Bigelow Aerospace without dipping into capital: "We won't be eating the leg of the cow."

The cash cow is a chain of extended-stay hotel/apartments in Nevada, Texas, and Arizona, called the Budget Suites of America, that Bigelow founded in 1988. He currently owns 16 Budget Suites, which, along with other properties, provide a steady flow of rental income. That, plus profits from his other ventures, is enough to keep Bigelow Aerospace going for now.

Asked about problems with the Genesis modules, he's open and direct. "Both spacecraft are operating well, but a few weeks ago we had a glitch on Genesis II," he says. "One of the subsystems went offline, and we had to reboot the spacecraft's onboard computers." I had noticed a 10-item troubleshooting list scrawled on the whiteboard in the adjoining conference room ("Software bug?" "Radiation spike?") and suspected as much. The problems were affecting flight attitude, he says, which can be adjusted with passive (non-propulsive) flight controls. Without a reboot, the craft could have dropped to a lower orbit, or worse.

The reboot "was a little tense," Bigelow admits. "You never know if the spacecraft is going to come back to life." The first module, "Gennie 1," as mission controllers call it, had to be rebooted last December, and again a few months later. The engineering team never got the faulty subsystem back online after the first reboot, so radiation seems the likely culprit. Luckily the system was not flight-critical.

The real bugs, the ones in the Biobox, are dead—"Kaput," Bigelow says—victims of a six-month delay during which



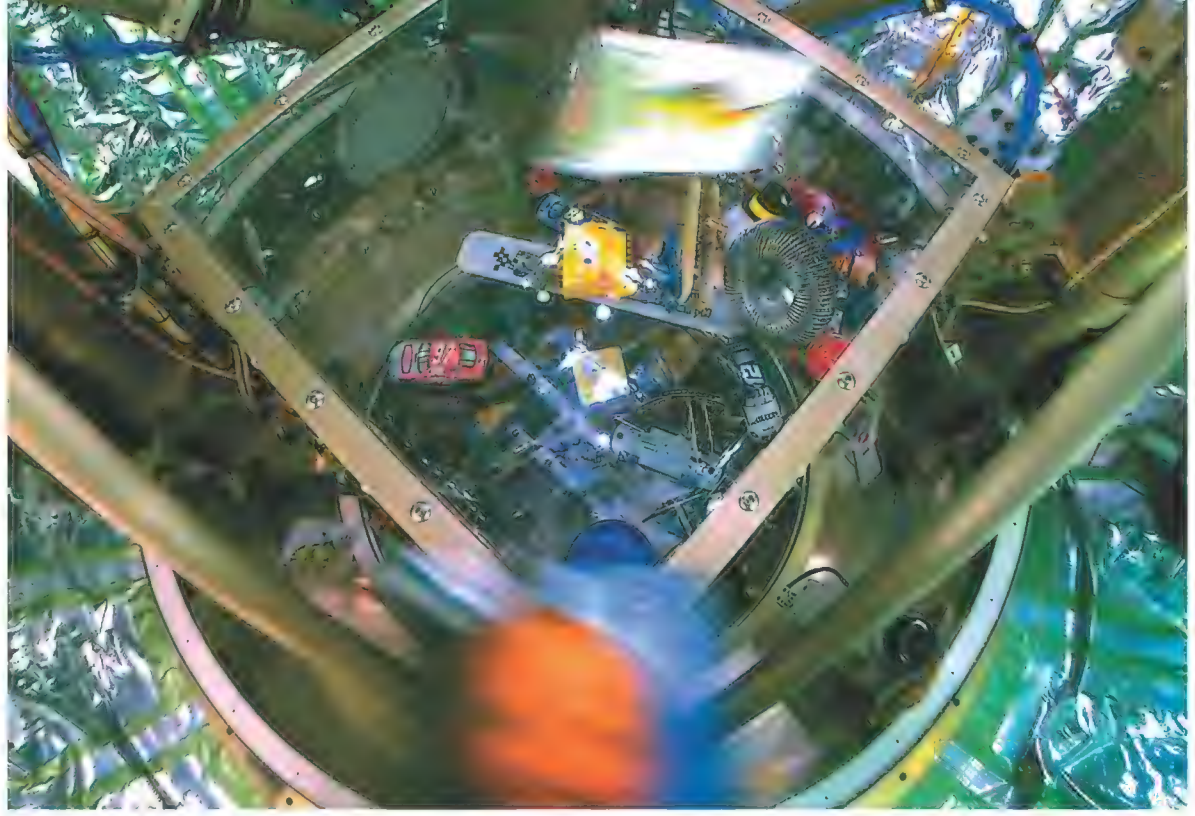
ART BELL

The world's first privately owned space stations are run from Bigelow's mission control in north Las Vegas.

the payload was in cold storage in Russia. They never even made it to launch day. And as of early September, the bingo game hadn't been turned on due to communication problems with ground stations. Bigelow currently has operational stations in Nevada, Alaska, and Hawaii. He's commissioning another in Maine, which will ensure full coverage of North America, and plans to build or lease several more around the world. Two of the existing stations have had troubles. Alaska has been down one or two days a month, and Hawaii has been out 50 percent of the time.

At this early phase of the program, such difficulties don't bother Bigelow. "We're gaining experience and learning how to operate missions on orbit," he says. "We want to test to fault. That's our goal." He seems completely undaunted by what is, after all, still a part-time job for him. Nor does he brag about the success he's had so far. "We haven't accomplished that much yet," he says.

Even so, just a few weeks before my visit, Bigelow had raised his bet. He announced that due in part to the rising costs of Russian rockets, he would skip the next planned launch, of an intermediate-size module called Galaxy, and proceed directly to the human-habitable Sundancer, a 6,300-cubic-foot module, which would be in orbit by 2010. A gutsy and exciting move, to be sure. While other players in the nascent commercial space sector were slipping their schedules, Bigelow wanted to go faster.



BIGELOW AEROSPACE, INC.

For $295, you could "Fly Your Stuff" inside a Bigelow module and watch on the Web as it floated by the cameras. Photos and other mementos were favorite items to send up.

"If a few years ago anyone in the space industry told you they could develop and launch two new satellites for under $100 million, they'd be stringing you along," says former consultant Courtney Stadd. "But Bigelow has done it."

ROBERT BIGELOW DIDN'T set out to put habitats in orbit, or even start his own space business. In 1996, he decided to invest in "two or three" of the emerging commercial space companies. Once on the inside, "I was shocked and amazed," he says. "They may have known rocket science, but they had no understanding of the science of business." The companies promised great things in PowerPoint while running huge deficits and living from one government contract to another. Bigelow declined the board seats offered him, divested, and went his own way.

In 1999, he founded Bigelow Aerospace with the notion of building his own spaceships. His early ideas were fanciful nonstarters, like a cruise-ship-style spacecraft that could accommodate 100 passengers on a round-the-moon voyage. Then he came across some magazine articles, including one in *Air & Space/Smithsonian* ("Launch. Inflate. Insert Crew," Apr./May 1999), about a $100 million NASA project called Transhab, a lightweight inflatable habitat, made of tough, puncture-proof fabric, that was designed to shelter astronauts on Mars. Under Congressional scrutiny, the program was in danger of being cut. One detail caught Bigelow's attention: Transhab was considered by its inventors to be potentially suitable for docking with the International Space Station.

It was an "aha" moment. With their lower weight and smaller volume, Bigelow reasoned, inflatables could be space stations themselves, providing habitats that would be far less costly to launch. Within months, NASA was indeed forced to drop Transhab. Bigelow immediately began negotiations with the agency to license the technology under the Space Act Agreement. Whereas NASA had previously been "resistant to private sector development," according to Mike Gold, Bigelow's Washington, D.C.-based corporate counsel, the space agency was more cooperative during the transfer process. Gold now characterizes the company's relations with NASA as "excellent."

By 2002, Bigelow had secured the rights to Transhab's patents, about eight in all. But the technical information accompanying the patents was sketchy. "There was no book of instructions," he says. Nonetheless, he and his new hires (engineers with commercial-satellite experience from TRW, Boeing, Raytheon—though initially none from NASA) set to work, filling in the gaps as best they could. As part of the licensing agreement, NASA sent former Transhab team members to Las Vegas. But they had only vague knowledge of how and why certain things had been done. Bigelow recalls that "very often they would study a problem, then say, 'Well the guy who really did that was Schneider, and you can't get him anymore.' " After this happened about five times, Bigelow started asking, "Who the hell is this guy Schneider, and why can't I get him?"

Schneider was William Schneider, considered the father of Transhab. He was no longer at NASA, and therefore not part of the licensing deal, having retired as a senior engineer in 2000. Finally, in 2002, Bigelow heard that Schneider had taken

a post on the engineering faculty at Texas A&M University and might be available. Bigelow invited him and his wife for a visit. Schneider arrived shortly afterward to see his orphaned project resurrected on the floor of a plant in north Las Vegas. He looked over the work carefully. "I was absolutely amazed at what they had done," Schneider says. "They had taken some of the patents and made [those technologies]. It wasn't exactly right, but they had made big modules out of aluminum and they had some inflatable versions." But, he adds, "It wasn't mature at all. It was more of a show thing."

There was plenty to do, and Schneider got to work. Now he spends a few days every two weeks working in Las Vegas as a consultant, staying at a nearby Bigelow Budget Suites. He describes the structural core of the Sundancer module, which he says is mostly designed (the fabrication building is off limits to me on this trip): "We'll have eight longerons—longitudinal beams—run the length of the spacecraft. And we'll have honeycomb panels in between, locking and holding it all together, so it works like one structural beam." The core is surrounded by a multi-layer skin and debris shield, which are launched folded around the core. Schneider likens the inflatable habitat to a football with a bladder and pigskin on the outside: "The pigskin takes the real forces but couldn't hold the gas, and the rubber holds the gas but couldn't take the forces." Once in space, the habitat expands to full volume in less than 30 minutes, with gas pushing out the Vectran outer skin to a pressure of 10 pounds per square inch. At 10 psi, Bigelow likes to remind skeptics, it's harder than steel.

Since acquiring the inflatable technology from NASA, the company has filed for additional patents. One of the most recent, for a micrometeoroid and debris shield, was granted in April. The shield disintegrates incoming debris, breaking it up into small, harmless bits that can't penetrate the skin of the module. Bigelow is justifiably proud of the innovation—the patent carries his name as the sole inventor.

"He's kind of like Howard Hughes developing flush rivets and such," Schneider says. "He's not going to sit back, you know. He's going to be in the middle of it."

Because of its greater weight (some 19,000 pounds), Sundancer will have to ride a much larger rocket than Genesis did. Bigelow intends to launch by 2010 even if he can't get a crew up there right away. He would leave Sundancer in orbit for three to five months, pressurized, then send two astronauts up for two "housekeeping trips." The larger, seven-person BA 330 module will remain on the ground for years if need be—until there's a reliable, affordable way to launch people into orbit.

Last April, at the National Space Symposium in Colorado, Bigelow laid out his business plan, which calls for three full-size space stations in orbit by 2017, and more than 30 launches a year to service them. Projected price to customers: $14 million per astronaut per month in space, most of which would go for transportation costs. The company is targeting two types of client: governments who want a work place with "significant hang time"

One patent, for a debris shield, carries Bigelow's name as the sole inventor. "He's kind of like Howard Hughes developing flush rivets and such," says Schneider. "He's not going to sit back, you know. He's going to be in the middle of it."

BIGELOW AEROSPACE, INC.

One photo returned from Genesis II last summer was a birthday surprise for Bigelow's 15-year-old granddaughter Blair: her name stitched on the spacecraft's fabric exterior.

in microgravity, and companies involved in biotech, software, and other industries who would sign longer leases to do research and even manufacturing. Customers could rent an entire module for $88 million a year.

In Bigelow's business plan, space tourism plays only a minor role. He is emphatically *not* running space hotels. And he's not counting on NASA or military contracts. He fears getting bogged down in bureaucracy, and wants the stations to be used only for peaceful purposes. His goal, he said in Colorado, is to become nothing less than an orbital Hudson Bay Company, selling goods and services in a thriving space economy. "There are 225 active astronauts in the world," he told the gath-

WILLIAM HARTENSTEIN (2)

Bigelow's inflatable modules have a lattice framework inside (above). Outside is a tough fabric hide that, when pressurized, is harder than steel. Right: Early test articles on the Bigelow factory floor. The Genesis modules are the intermediate size.

ering. "After 45 years, shouldn't there be a zero at the end of that figure?"

The audience was polite and attentive, but after Bigelow stepped down, I overheard one of the attendees mutter, "Yeah, I did spreadsheets like that in the 1990s, but there was always a few extra zeroes on the end." Translation: Bigelow's service might end up having a per-astronaut-per-month cost of not $14 million but $140 million.

Private space stations have been attempted before. Joe Allen, a former astronaut who flew two space shuttle missions before leaving NASA in 1985 for the private sector, says, "I spent a number of years and untold amounts of money, other people's money," on a plan to build and operate a small space station. For a projected cost of $1 billion to $2 billion, the Industrial Space Facility would have served as an orbiting "construction shack or outbuilding" leased to NASA. In the end, the scheme was defeated by the glacial pace of the agency's decision-making and skeptical outside reviews.

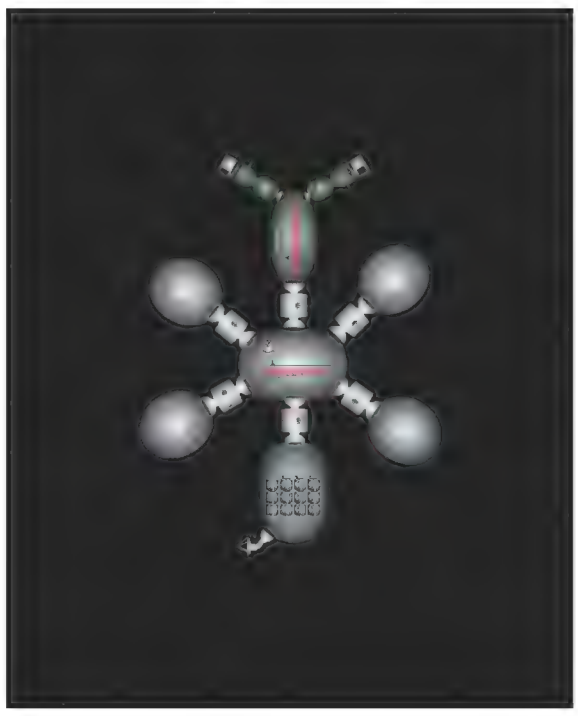
Allen thinks that anyone proposing a commercial space habitat faces two kinds of challenges: technical, which he says are relatively easy, and business, which are hard. Though he has not reviewed Bigelow's plans, Allen speaks from experience. "It's not clear what a revenue source would be to pay for something like [a station], and there's no reason to do it privately except as a hobby," he says. "My question is: 'Who is the customer?'" I explain Bigelow's plan to attract corporate and non-U.S.-government clients, though none have signed up yet. I describe it as a "build and they will come" approach. "That's where I'm skeptical in the extreme," Allen says. He concedes that Bigelow may succeed where the Industrial Space Facility failed 20 years ago, but says, "It's going to take a bold individual. The upfront costs are huge."

Howard McCurdy, a professor of space policy at American University in Washington, D.C., thinks Bigelow may be one of those catalytic individuals. "He's the Leland Stanford of the 21st century," he says, referring to the co-founder of the Central Pacific Railroad. But, says McCurdy, there's a critical difference. The railroads had a government subsidy—free land they could commercialize. For space, he asks: "Where's the subsidy?

"I've never seen a major new technology that was developed fully without a subsidy or incentive," he adds, recounting how the 1925 Kelly Act launched the airline industry by guaranteeing airmail routes to commercial carriers. Both Allen and McCurdy think that without NASA or some other deep-pocket agency as the major "anchor tenant," a private space business is doomed.

Yet Bigelow is determined to go it alone, without NASA or Pentagon help. He frequently compares his space venture to real estate deals, saying that in principle, his space station is no different from a $50 million office building.

Perhaps. But office buildings aren't surrounded by a deadly vacuum, or constantly threatened by radiation and meteoroids. NASA spends millions on technology to keep astronauts safe in orbit. What makes Bigelow think he can do it for less?



BIGELOW AEROSPACE, INC. (3)

Bigelow has brought playful touches like orbital bingo to commercial space. Visitors to the company's Web site can create their own space station by dragging and dropping cartoon-like modules, then posting the results.

When it comes to what aerospace engineers call ECLSS—environmental control and life support systems, the technology that keeps astronauts breathing clean air and drinking pure water—Bigelow says that by the time he puts people inside Sundancer, he'll have options. "We will use a mixed menu if we have to, from the Russians and others," he says. He'll use proven ECLSS systems at first, while his engineers develop technology they can test in Bigelow habitats.

The major ECLSS suppliers to NASA will be no help, he believes. They won't even consider working for a commercial venture unless it's for a cost-plus contract, according to Bigelow. "That's how you get to where buying a $19 million toilet is [the cheapest option]," alluding to the amount NASA reportedly paid the Russians for their space station plumbing technology.

David Klaus, a professor of engineering at University of Colorado and an expert on ECLSS, doesn't discount the idea of getting life support in space cheaply. "I hate to use a cliché, but [ECLSS] is not rocket science," he says. "It's basically HVAC—heating, venting, and air conditioning—in space." As to whether Bigelow can do the job for a fraction of what NASA spends, he says, "You can go into space with a couple of scuba tanks. You can go with 'big, dumb, heavy' solutions that are reliable. The higher costs come when you want to combine low mass and high reliability."

Either way, Bigelow doesn't lose sleep over it. What he does worry about, a lot, is whether he will be able to find a ride to orbit that he can afford. "Transportation is the showstopper," he tells me. No human-rated rockets, no astronauts in orbit, no space business.

Bigelow has contracted with another "new space" pioneer, Elon Musk of California-based SpaceX, for flights on Musk's planned Falcon 9 rocket in 2010. But Musk, after an investment of $100 million and two launches, has yet to make it to orbit. To cover his bet, Bigelow also entered into an exploratory agreement with Lockheed Martin to study the possibility of human-rating the proven Atlas V launcher. Meanwhile, he's sent consultant Courtney Stadd searching the world for cheap launch systems—so far with no luck. "It looks like there'll be no reliable, affordable launch

Like NASA's, Bigelow's station (opposite) can expand. The planned 45-foot BA 330 modules would each hold seven people.

system until mid-next decade," Stadd laments.

So, rather than wait around for the launch industry to deliver, Bigelow is reluctantly entering the arena as a player. "I didn't want to fight a two-front war," he says. But, by the time this article is published, he expects to have announced his investment in a new space capsule. "We're making a capital investment in the creation of a capsule for crew and cargo, one that will have a common interface that can be placed on a [Russian] Proton rocket, a human-rated Atlas, or possibly Musk's Falcon 9," he says. It will be a seven-person capsule, big enough to carry people to the large BA 330 stations. "We won't be designing the capsule, but we'll be very active investors," he says.

BIGELOW WAS BORN IN Las Vegas and has spent his entire life there. ("Haven't gotten very far, have I?" he quips.) Born under the West's big sky, he is a man with big ideas. The ringtone on his cell phone is "Yippie-yi-yo, Yippie-yi-yay," the chorus from the cowboy ballad "Ghostriders in the Sky."

He was 13 when in 1957 the Soviets launched Sputnik, and in his youth he was fascinated by his grandparents' oft-told story of a 1947 encounter with a UFO, a red object streaking overhead as they drove across the desert. "When you grow up here, there are so many people who have these profound experiences" of alien encounters and sightings, he says. "It does affect you."

I've brought up this topic gingerly, but Bigelow jumps right in without hesitation. "Oh, you mean the UFOs," he says, chuckling, then looks me right in the eye. "I have no doubt." Though he's never had an encounter, he has spent years tracking down reports of alien visits. "I've personally done 235 interviews, just like you're doing, with a notepad and tape recorder." He is most interested in close encounters—"Things 100 or 200 feet in front of you that are undeniable."

He tells me about his Utah ranch (often called Skinwalker Ranch, it was the site of reported alien cattle mutilations), which he bought in the mid-1990s and

BIGELOW AEROSPACE, INC.

McCurdy calls Bigelow "the Leland Stanford of the 21st century," referring to the co-founder of the Central Pacific Railroad. But, he says, there's a critical difference. The railroads had a government subsidy. And without NASA or some other deep-pocket agency as an "anchor tenant," the plan could be doomed.

which still functions as a "living library for research." Around the same time he created and funded the National Institute for Discovery Science, which operated until 2004. Before it went dormant, it was the place to call if you wanted a multidisciplinary investigative team—forensics experts, ex-FBI agents, even a veterinarian—to come document or investigate your alien encounter. Often Bigelow would accompany the investigative teams, flying them to sites in his jet.

He worries about what will happen when contact with aliens is made, and whether civilization will be prepared. "Will people go to the gun store? Buy up everything? Hide in their houses?" he asks. "Will deliveries get made, or will people go to work?" This is clearly a topic of deep, continuing interest to him. (Bigelow Aerospace's mission control screens feature an iconic large-eyed alien, and Bigelow has promised to share any "anomalous video" from Genesis I or II with other seekers of aliens.)

Our interview concludes. As I wait for the security guard to escort me from the building, I look out over mission control, now dark. The twin Genesis satellites are on the other side of the world. Turning around, I can see Bigelow immediately return to some task, his assistant bringing him a sheaf of messages that have stacked up while we've been talking.

Back in March, before we'd even talked on the phone, I had my own personal encounter with a spacecraft—one of Bigelow's, as it turned out. Planning to watch the live Webcast of SpaceX's Falcon 1 launch from the South Pacific, I took my dog out for her walk early. It was an exceptionally clear, dark night in Connecticut. I stood and stared up at the stars for several minutes. Then I spotted a satellite with a bright orange cast, magnitude 2.5 or brighter, transiting the sky in a north-northeasterly direction, between the constellation Leo and Saturn. I tracked it easily for more than a minute and a half until it disappeared over the Atlantic, heading toward Newfoundland. That can't be Genesis, I thought.

When I checked a satellite tracking Web site back at home, I learned that, sure enough, it was Genesis I, NORAD ID No. 29252. I felt an undeniable thrill at seeing it and watching the Falcon launch on the same night. Privately funded, entrepreneurial spaceflight was happening before my eyes.

F-117s gathered in 2006 to celebrate reaching 250,000 hours flying from New Mexico's Holloman Air Force Base.

UNG

BY BILL SWEETMAN

LAST MARCH, SIX LOCKHEED MARTIN F-117A NIGHTHAWK FIGHTERS took off from Holloman Air Force Base and made their last landing at Tonopah Test Range in the remote northwest corner of Nevada's Nellis Air Force Base. Their wings removed, the aircraft will be stored in secure hangars there rather than in the customary open-space aircraft graveyard in Arizona. The retirement of the jet, scheduled for April 2008, is not a surprise.

Despite its success in the first Gulf War, in which the F-117A fleet was credited with disabling Iraq's air defense system during the opening stages of the conflict, it has been many years since the Pentagon invested significant money in the F-117. Neither has its reputation for invincibility survived; that died in 1999 when a wily Serbian crew shot one down with a vintage Russian missile. And although there is no direct replacement for the F-117A, there are now both fighters and missiles that can do part or all of its job.

The seeds of the stealth fighter's obsolescence were sown at its cold war conception, when it was rushed into production in 1978 as a way to defeat Soviet air defenses in the event that NATO was called upon to defend Central Europe.

SENIOR AIRMAN BRIAN FERGUSON/USAF

CONVENTIONAL WEAPON

After a short, controversial career, the F-117 passes the stealth baton.

LOCKHEED MARTIN

The mostly aluminum fuselage is clearly seen here, *sans* radar-absorbent skin, during assembly.

Because it was designed and built quickly, the airplane had limitations that could not easily be eliminated. But it was a historic achievement nonetheless, a first-of-a-kind that will pass on its design philosophy and operational lessons to future generations.

The F-117 might have had a longer period of gestation had Soviet-made missiles in Egypt and Syria not mauled the skilled Israeli air force during the 1973 Yom Kippur war. An assessment by the Pentagon's Defense Science Board the following summer made depressing reading: The more sophisticated defenses in Eastern Europe would likely prevent NATO air forces from hitting their ground targets.

The assessment helped fuel interest in the idea of a low-observable or "stealthy" airplane, leading to the award of the first study contracts in January 1975. And, as the summer of that year passed, it was increasingly clear that researchers at Lockheed Martin and Northrop Grumman were on the edge of an astounding breakthrough, achieving reductions of radar cross-section (RCS, the measure of an object's size on radar) that had been considered impossible.

The key to the breakthrough was a compromise. Engineers had known that it was theoretically possible to use shaping and materials to make an object seem smaller on radar. The snag was that calculating the RCS of a complex shape like an airplane, from all angles, over a range of radar wavelengths, while taking into account the effects of radar-absorbent material, was vastly complicated. The computers of the early 1970s simply weren't up to it.

It was Denys Overholser, an electrical engineer at Lockheed's Skunk Works, who realized that the problem could be worked from both ends. While more powerful computers and new software would help solve the RCS equations, the airplane could also be redesigned to make the equations simpler. That is why the Lockheed design that took shape in the summer of 1975, breaking the tradition of every airplane before it, had no curved surfaces at all.

The discovery of a 1964 paper published by Russian mathematician Pyotr Ufimtsev, which showed that a radar re-

A shadow leaving a shadow, an F-117A lands at Holloman. Early on, wags dubbed the aircraft "the Hopeless Diamond."

JOE OLIVA/JETPIX.COM

TOM TROWER/NASA AMES RESEARCH CENTER

The stealth technology programs that developed the F-35 Lightning II borrowed heavily from the F-117 design experience.

turn is proportional to the arrangement of edges of an object, not the size, inspired a new shape of airplane (see "The Invisible Men," Apr./May 1997). The entire shape was made of flat plates and covered in linoleum-like, radar-absorbent material.

Nobody had any illusions that the resulting airplane would set records for range, speed, or maneuverability, but the compromise was vital to Lockheed's winning the contract for the Experimental Survivable Testbed, or XST, in April 1976. It would also prove critical in the design of the F-117—and, in the long term, seal its fate.

Air Defense Assassin

In November 1978, after the XST prototypes (renamed Have Blue) had flown, Lockheed was awarded a contract to develop the aircraft, under the code-name Senior Trend. The Pentagon's leaders had recognized the power of stealth and initiated a secret debate about how to exploit it.

The final decision was to field, as quickly as possible and in complete secrecy, a stealth aircraft designed primarily for one mission: putting a bullet through the brain of the enemy's air defense system in the first hours of war.

Lockheed would build five development airplanes while starting an initial batch of 20 production aircraft. The goal was to fly the first aircraft in July 1980. The need for speedy design defined the F-117. Its external shape was as close to Have Blue as the designers could get, while achieving a just-acceptable range, altitude, and landing speed.

Overholser believed that it was possible to incorporate curvature on the wings, but he could not prove it. "Very simply, the configuration of the F-117 was entirely designed by radar signature requirements," engineer Alan Brown summed up in a 2003 paper. "No compromises were made in this respect at all."

Neither was there time to design parts for the entire jet. The navigation system came from the B-52 bomber. The engines were from the Navy's F/A-18 Hornet fighter. The infrared targeting system, from Texas Instruments, was assembled from parts of other systems. The F-16 contributed the computers and flight control system. The biggest cockpit display was from the Navy P-3 Orion patrol airplane.

Like the Have Blue, the F-117A was covered with radar-absorbent material—almost a ton of it. It was made in the form of flat sheets, cut to fit the skin panels, and glued in place. A putty-like material dubbed "butter" filled the gaps between the sheets. The engines were concealed from radar by Chrysler-like grills, and the hot exhaust gas from the engine was expelled through slits.

The jet had no radar. There were ideas for "low probability of intercept" radar that could work without giving away the jet's position, but the technology could not be ready in time. (Such LPI radar uses tricks with modulation, frequency hopping, low power, and huge bandwidth to obscure its signal.) The aircraft's use would be confined to attacks under the cloud base or in clear weather.

Even so, the jet was hard enough to build. The engineers were "inventing to schedule," solving problems like keeping ice from forming on the inlet grills (a chemical-dispensing squeegee is hidden in the wings in front of the inlets) and on the air-data probes. They concealed the infrared sensor turrets from radar with a titanium wire mesh.

The haste paid off. The aircraft reached

AIRMAN JAMAL SUTTER/USAF

A ground crew locks a 2,000-pound bomb onto an F-117. Used in Iraq in 1991, laser-guided weapons heralded modern warfare.

operational capability in October 1983, later than envisioned, but still only five years after the go-ahead on development. The angles of the wings were calculated to disrupt the radar waves as they scattered away from the aircraft and thus prevent them from returning to the source. Likewise, all the doors and opening panels featured saw-toothed forward and trailing edges to disrupt reflection of radar.

For all the hype, the aircraft was far from invisible. The RCS figures remain classified, but the airplane was more visible to radar from the sides than head-on. Planning the missions was difficult—because the jet could be seen by radar, the track had to be carefully adjusted to minimize the craft's exposure.

The Model A of Stealth

Once Have Blue showed that attaining stealth was possible, the Air Force sought to replace it, and research began in earnest. Northrop, Boeing, and General Dynamics launched programs plumbing shapes and technologies that promised greater stealth and better aerodynamics.

By the time the F-117A entered service, Northrop was flying the AP-1 Tacit Blue demonstrator, a stealth aircraft with curved surfaces, no inlet grills, and low-probability-of-intercept radar. The Air Force started studies of a stealthy supersonic fighter.

Al Piccirillo became the program director for the Air Force's Advanced Tactical Fighter project in 1984. "The B-2 was there and the ATF was in development," he says. "The feeling was that we had moved beyond the F-117, and the big effort was to fix what was wrong."

The new jet had quite a lot wrong. The onboard computers did not have enough processing power. A rudder weakness limited speed. And maintenance was "a nightmare," says Piccirillo.

In January 1984, the jets needed 113 hours of maintenance for every hour they flew. And at any given time, only 11 percent were judged mission-capable. The kludged-together quality of the avionics was one problem, but it was the stealth technology that was the worst.

The tailpipes were lined with ceramic bricks, made from the same quartz-like material used on the space shuttle. Each tile had to be cemented in place individually, and the seams between them filled with a putty-like material. Even a small gap could act like a tiny inlet, channeling the already blazing exhaust gas and heating it enough that it would burn through to the metal underneath.

The biggest problem resided in the fundamentals of stealth. When a radar pulse lights up an airplane, electrical currents form all over its skin—and when they hit an obstacle or jump a gap, they cause tiny sparks or scintillations, which the radar can detect. The F-117 controlled these with a coating of absorbent material, but if the coating had even the smallest gap or crack, it could betray the aircraft.

The aircraft had doors—the cockpit canopy, the landing gear and weapon bay doors, engine access doors, and so on—but they were heavy because they had to seal perfectly. The designers tried to make sure that components that needed maintenance could be reached through the doors; some of the airplane systems could be accessed through the weapons bays.

Often, though, what would have been a routine repair on another aircraft required scraping off the material from an entire panel, replacing the material, and, finally, re-sealing it.

F-117s and their heirs, F-22 Raptors, at a Red Flag exercise. Every future U.S. Air Force fighter will be built to be stealthy.

Early in the 1980s, the Air Force planned to build an improved B model, but the money for the project was diverted into fixing the A. Replacing the computers started in 1984, and the first updated airplanes were in service by 1988. By that time, an automated mission planning system was operational. A new tail lifted the speed restrictions.

The radar-absorbent material was improved across the 59-airplane production run—a mixed blessing for the overworked maintainers, because although the new aircraft were better, the Air Force ended up with four different stealth configurations, each needing different repair procedures.

Piccirillo now says, "1988 was when we started to get some real capability" in the F-117. So the jet that became the hero of the first Gulf War was not quite the same as the aircraft that had entered service.

The success of the campaign became an opportunity for Lockheed to plead for a second life for the fighter, but in the early 1990s, many weapons systems and philosophies competed for backing.

During the F-117's career, its avionics were updated to allow pilots to receive orders and change missions in flight.

LEFT: PAUL WEATHERMAN/LOCKHEED MARTIN; OPPOSITE: RICHARD VANDER MEULEN

Staff Sergeant Robin Walker (left) reports no foreign objects in the inlets to Staff Sergeant Greg Slavik prior to takeoff from Nellis Air Force Base in Nevada.

Within months of the 1992 election that put Bill Clinton into the White House, every new and prospective tactical aircraft program had been canceled in favor of a project called Joint Advanced Strike Technology (JAST)—the precursor of the Joint Strike Fighter program, and the resultant F-35 Lightning II. It was the end of the road for an advanced F-117.

The jets that were already in service continued to get upgrades. For example, the radar-absorbent material was stripped off, and new access panels were cut in the skin. The old linoleum-like stuff was replaced with sprayed-on material that incorporated "zip strips," which the maintainer could remove to expose the edges of an access hatch. That and other changes brought the jet's mission-ready rate to an excellent 89 percent.

But the Air Force had allowed its unique fighter to become separated from the rest of its combat units. For almost a decade, the F-117 force had operated in secrecy at Tonopah Test Range. Not until 1992—after its success in Operation Desert Storm—did the Air Force move the fighters to Holloman. The idea to integrate the stealth fighters with the "iron jets" in the rest of the force occurred too late and too slowly. A senior F-117 pilot, Colonel Thomas "Bulldog" Shoaf, commander of the F-117 Weapons School, said the Air Force was slow to tout the full capabilities of a stealth aircraft, even among its pilots.

"There were times when we weren't cleared into how well we were stealthy against the threat," he told participants of a military conference in London. The result was "a perception in the combat air forces that the F-117 was none of their business, a stand-alone system."

It was during those isolated years that the Nighthawk force suffered its first and only combat loss.

Nadir Over Serbia

On March 27, 1999, an F-117A that had just bombed a target in Serbia was shot down 28 miles northwest of Belgrade. The weapon that shot it down was a veteran S-125 Neva-M missile system.

The other side of the story emerged in late 2005, when the Serb commander whose battery had planned the attack discussed it in detail for the first time. Colonel Dani Zoltan—whose traditional

The legacy of the F-117 design becomes evident when comparing the placement of inlets and pilot on an F-22 (opposite).

LEFT: TONY LANDIS/NASA DRYDEN

Hungarian name had not been released because it wasn't Serbian, a testament to the bad blood between the two nations originating in Hungary's World War II invasion of Yugoslavia—emerged as an energetic and original leader who used good tactical sense and modified equipment to down the world's most sophisticated stealth aircraft.

To keep his radars and operators from being attacked, Zoltan kept them on the move. He led the Third Battery of the 250th Missile Brigade on more than 50,000 miles of blacked-out travel in the 78 days of the war. He also made unspecified modifications to the P-18 radar.

Resembling a Rube Goldberg assembly of housetop TV antennas, the P-18 differed from most radar because it operated in the VHF waveband, transmitting at a much lower frequency than most other radars. The radar-absorbent material covering the F-117 is less effective against VHF radars.

The jet's primary defense against VHF resides in the wing edges, which take the form of deep and effective absorbers, called an "electromagnetic shock absorber" by chief engineer Alan Brown in a 1992 lecture.

Avoiding detection by systems like the P-18 required a combination of careful planning, operational security, and tactics. But Zoltan's hyperactive battery couldn't be pinned down. Serb agents were tracking takeoffs from the F-117s' base in Aviano, Italy, and airspace restrictions indicated that the fighters were following very similar routes, night after night.

According to Dani, when the F-117A was head-on at 26,000 feet and eight miles out, the battery fired two missiles.

AP IMAGES/VLADIMIR DIMITRIJEVIC

Russian television images of an F-117A shot down over Serbia. The Russians used the debris to improve air defenses.

Each would have closed the distance in seconds. The pilot, Air Force Lieutenant Colonel Darrell Zelko, has never specified how much warning he had of the attack. One still-classified aspect of the F-117 is whether it carries any kind of radar warning receiver. If it does, even the most comprehensive studies of the aircraft have not mentioned it, nor has it been mentioned as part of any upgrade.

A December 2006 account of the shootdown in *Air Force* magazine says only that Zelko's "routine suddenly was shattered by indications that Serbian air defense systems had targeted his aircraft." (Zelko ejected and was rescued by an MH-60 Pave Hawk helicopter six hours later.)

The shootdown led to such changes as the formation of an F-117 weapons school to develop, formalize, and train in tactics, and an increased emphasis on training with other forces, including the jet's first participation in Red Flag war games. "Stealth is not perfect, and we still count on other assets to improve our capability," Shoaf told the London conference.

As other systems started to encroach on the F-117A's battlefield jobs, the aircraft's retirement loomed. One early herald of the end of the Nighthawk's service life came in 1994, when the Air Force decided to add a guided bomb on the F-22.

The only guided bombs available when the F-22 was designed used laser designation, and the F-22 flew too high for that to work. The picture changed with the development of the GPS-guided Joint Direct Attack Munition and the realization that better computers could make it possible to get a high-resolution ground image from the F-22's radar. The fighters could drop ordnance on pinpoint positions.

And then came the missiles. The view from the F-117's strange cockpit is so limited that the mission does not call for the pilot to see the target with the naked eye. The airplane's navigation system would guide the aircraft to a point where the infrared sensors could see the target.

Then the pilot would find the exact aim point within the image and lock the laser designator on to it. But missiles such as the Joint Air-to-Surface Standoff Missile (JASSM), which entered service in 2003, can do the same thing, comparing the image from an infrared camera to digital images of the target area.

Neither the JASSM nor the F-22 could replace the F-117 directly, but each reduced the number of tasks that only an F-117 could perform.

By 2005, according to Major Doug Downey, in charge of tactical training for the fighter, the F-117 force was focused on just a handful of missions. One

RICHARD VANDER MEULEN

LEFT: TECH. SGT KEVIN J. GRUENWALD/USAF

USAF

The 37th Tactical Fighter Wing waits to launch for Saudi Arabia during Operation Desert Shield. Called fighters, the F-117s were actually used as precision bombers.

was "eyes on target": when no missile could be trusted to ensure that the target was hit, and it was critical to verify that the correct target had been struck.

Another F-117 mission was carried out when the rules of engagement demanded that harm to surrounding people and buildings be kept to an absolute minimum. The F-117, with its ability to deliver a 2,000-pound warhead with precision, could also hit tougher targets and sturdier bunkers than any missile.

One of the 1990s avionics upgrades had included time-over-target control, or four-dimensional navigation. If the requirement was to have the bomb go off at a precise moment, the F-117 could do it.

But the final blow against the future of the F-117 was dealt by expensive wars in Afghanistan and Iraq. Struggling to maintain its budgets and protect pet projects like the F-22, the Air Force has targeted older aircraft like B-52s, U-2 spy airplanes, and F-117s for retirement.

In 2006, the Air Force announced that the Nighthawk would be gone by 2008. New Mexico's Congressional delegation complained briefly, but was placated with the promise of an F-22 wing at Holloman. This time, the F-117 could not hide from its foes.

Living Legacies

Compared head-on, the F-117A and the F-22 don't look very similar. But turn one picture upside down and the relationship is suddenly very clear. (Hint: See the photographs at the bottom of the previous two pages, and look at the placement of the blocky inlets.)

Lockheed's original Advanced Tactical Fighter design was very closely based on the F-117—or, to be more exact, what a second-generation F-117 might have been, with curved wing and tail surfaces, rounded edges, and new, lighter radar-absorbing materials. In turn, Lockheed's F-35 Lightning II, intended to be the linchpin of both U.S. and allied fighter forces for much of this century, is clearly a cousin of the F-22. These designs reflect a philosophy that remains unique to the Air Force: that a fighter should be designed primarily around stealth.

The U.S. Navy and European air forces have elected to build fighters (the Boeing Super Hornet, the Dassault Rafale, and the Eurofighter Typhoon) that use stealth technology to render hostile radars less effective, but are basically conventional, with weapon carriages and electronic jamming systems located outside the aircraft.

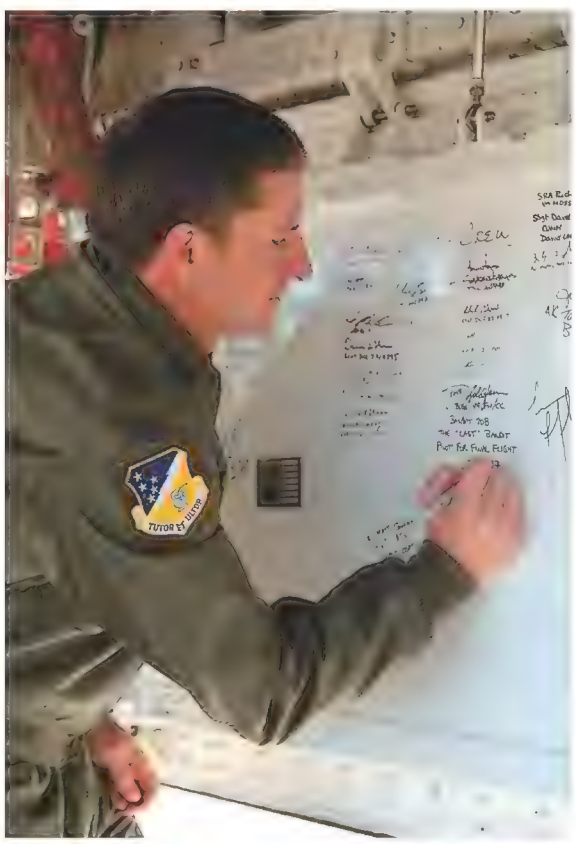
Dassault describes the Rafale fighter as not stealthy ("*furtif*") but discreet ("*discret*"), using a combination of stealth and low flying to avoid detection. Not surprisingly, Eurofighter and Dassault people claim that their aircraft are quite as capable as the F-35. They may not be as stealthy but they carry more weapons for attack and defense, and if you need the ultimate in stealth for certain targets, both fighters will carry missiles that can reach targets before the airplanes are in range of defenses.

But the biggest influence the F-117 exerted on the F-35 is doctrinal. The way that the new jet uses stealth is rooted in the F-117A's experience in the first Gulf War, which the planners had in mind when drawing up the specifications for the Joint Strike Fighter program (which developed the F-35) back in 1995.

HOLLOMAN AIR FORCE BASE

In that conflict, the F-117As had played the leading role in lobotomizing the Soviet-supplied Iraqi air defense system, allowing F-16s and F-15s to operate with relative impunity for the rest of the campaign.

Signing off: Brigadier General David Goldfein signs the bay door of a retiring F-117A under his fighter wing command.



AIRMAN JAMAL SUTTER/USAF

Faced with the task of building a tactical stealth attack aircraft that would cost less than the big, canceled A-12 Avenger II, Pentagon planners came up with a concept called "day one stealth": For the first missions of the war, the JSF would be a stealthy airplane with a limited bomb load, like the F-117, but once the enemy's defenses had been destroyed, it could be loaded with external weapons like the older fighters.

It's a great idea if it works—but the lesson from Serbia was that it did not, for two reasons. The air defenses did not want to get killed on the first night, so they sacrificed lethality for mobility, minimized the use of radar, and survived to harry the attackers throughout the campaign. They also abandoned the centralized Russian control model and improvised communications, using telephones.

Last May, a Russian television documentary partly lifted the veil on that country's stealth and counter-stealth research, showing that engineers there had reproduced and studied the signatures of U.S. stealth aircraft and exploited their vulnerability to long-wave radars since the 1980s.

A Nighthawk shows off its strange profile in formation with an F-4 Phantom (middle) and a T-38 Talon over New Mexico.

According to the program, new missile radars could "easily" detect stealth aircraft. Some of this may be posturing, but there is no doubt that radars have improved. For instance, it has long been theorized that radar could benefit from a "track before detect" technique, in which radars see targets so small they would normally be eliminated as noise.

The problem with this approach is that it requires looking at patterns in the noise over time, and there was simply not enough computer memory to do it. No longer: As computer memory increases, this tracking-before-detection capability becomes more robust.

It's much too early to write the obituary for stealth technology, and every military aircraft under development today incorporates it to some extent. In that way, at least, the legacy of the F-117 will endure, since that airplane was the first to take stealth from the laboratory to the battleground. The Nighthawk fought the way it was designed—leading the way for the rest.

How Things Work:

Chandra X

BY DAMOND BENNINGFIELD | ILLUSTRATIONS BY JOHN MACNEILL

FOR MORE THAN EIGHT HOURS LAST FALL, THE CHANDRA X-RAY OBSERVATORY STARED AT A NONDESCRIPT GALAXY 240 MILLION LIGHT-YEARS AWAY. IN THAT TIME, ONE OF THE DETECTORS INTERCEPTED EXACTLY FOUR X-RAY PHOTONS. IT SOUNDS LIKE A MEAGER HARVEST, BUT THOSE FOUR PACKETS OF ENERGY HELPED ASTRONOMERS REALIZE THAT THE GALAXY CONTAINED A TYPE OF EXPLODING STAR THAT HAD NEVER BEEN OBSERVED BEFORE.

When the Chandra observatory was aimed at galaxy NGC 1260 (nucleus at left), it revealed SN2006gy (at right), the second brightest supernova ever observed.

NASA/CXC/UC BERKELEY/N. SMITH ET AL.

Chandra, which is named for Nobel Prize-winning astrophysicist Subrahmanyan Chandrasekhar, who first calculated the ultimate fate of stars like our sun, is the largest and most sensitive X-ray telescope ever built. The spacecraft can produce full-color images of X-ray-emitting objects while measuring the intensity at each X-ray wavelength.

Stars, galaxies, and other astronomical objects all produce light, with a mix of wavelengths that depends on the object's composition and temperature. Cool interstellar gas clouds, for example, emit primarily longer, infrared wavelengths. Medium-hot stars like our sun peak at visible wavelengths, while the hottest stars shine brightest in the ultraviolet. X-rays come from the hottest objects of all, such as clouds of gas between galaxies or the bands of gas spiraling into black holes.

Earth's atmosphere absorbs X-rays, so X-ray astronomers must place their telescopes in space. The Chandra telescope was launched by the space shuttle *Columbia* in 1999 and is today operated by the Chandra X-Ray Center at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

Chandra completes one orbit around Earth roughly every two and a half days. Its highly elliptical path takes it up to 83,000 miles away. Most of the time, this path keeps Chandra clear of the Van Allen belts, rings of radioactive particles encircling Earth, so the telescope has to shelter its instruments from the radiation for only a small portion of each orbit.

An optical telescope uses a large, curved-glass primary mirror to gather light, but X-rays would penetrate such a mirror's reflective coating; an X-ray telescope's mirrors must be facing almost perpendicular to the path of incoming light so that the photons graze the surface like stones skipping across a pond.

Chandra has four pairs of mirrors. X-rays hit the top mirrors in each pair, then skip down to the secondary mirrors. "You need two bounces to have X-rays come to a focus," says Martin Weisskopf, Chandra project scientist at NASA's Marshall Space Flight Center in Huntsville, Alabama, which manages the program. Each mirror is most efficient at reflecting a particular range of X-ray wavelengths.

After bouncing off the mirrors, the X-rays travel down a 26-foot tube toward the telescope's scientific instruments, located at the other end.

Devices called gratings can be moved into the light path between the mirrors and the instruments. The gratings contain thousands of narrow openings that segregate the X-rays by wavelength. The intensity of radiation at each wavelength reveals the abundance of different elements, along with the object's density, temperature, and motion toward or away from the telescope.

Beyond the gratings are the scientific instruments. The primary one, called the ACIS, for Advanced CCD Imaging Spectrometer, uses a charge-coupled device detector, similar to those found in digital cameras, to record the position of each X-ray that strikes it, along with the X-ray's energy level. In many cases, this information can be used to determine which chemical elements are present.

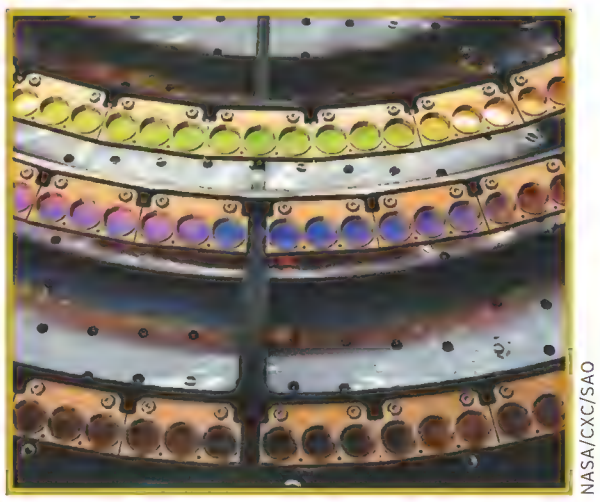
Most targets for Chandra are selected months in advance. But some time is reserved to study targets that appear suddenly, like the exploding stars known as supernovae. Such was the case with Supernova SN2006gy, which was discovered September 18, 2006, by an automated search program at the University of Texas' McDonald Observatory.

As astronomers began studying the star, they realized that it was an oddball. Compared to other supernovae, it took longer to reach peak brightness, it faded more slowly, and at maximum, it was several times more powerful.

Supernovae fall into two broad categories. One type is the destruction of a star

-Ray Telescope

X-rays enter Chandra's pairs of nested mirrors. They proceed to photon-counting instruments (inset above) at the telescope's other end, or they pass through circular gratings whose holes (below) separate the rays by wavelength.



NASA/CXC/SAO

at least 8 to 10 times as massive as the sun. Its core collapses to form a neutron star or black hole and its outer layers fall in, then explode. The other type is the complete destruction of the dead core of a star, known as a white dwarf. If the white dwarf steals enough gas from the surface of a nearby companion star, a nuclear explosion can occur, blasting the white dwarf to smithereens. Supernova SN2006gy seemed to fit in the latter category—until Chandra took a look at it.

A team led by David Pooley of the University of California at Berkeley used the telescope to peer into the star's galaxy 56 days after SN2006gy's discovery. The four X-ray photons it counted were "a clear, no-question-about-it detection," says Weisskopf. "Depending on the assumptions you make about the nature of the object that exploded and its history, you expect to see different amounts of X-ray emission. With the white-dwarf theory, we should have seen not four photons but 40,000." (Four photons weren't enough to enable the scientists to determine which elements were generating the radiation.)

To explain the blast, University of Texas astronomer J. Craig Wheeler resurrected a model from the 1960s that says the original star must have been at least 100 times as massive as the sun. The core of such a star is so dense and hot that some of its energy is converted to matter—pairs of electrons and their anti-matter equivalents, positrons. With less radiation pushing outward, the star's oxygen core began to collapse, triggering a thermonuclear explosion that ripped the star to bits.

Astronomers are still studying SN2006gy to confirm the mechanism. When they do, they will have to credit Chandra and its four little X-ray particles.

OUT IN THE Breezy

WITH LITTLE FANFARE (AND LESS STRUCTURE), THE BREEZY HOMEBUILT SPREADS THE MESSAGE: FLYING IS FUN.

BY JASON PAUR

AFTER GIVING MORE THAN 7,000 FREE RIDES over the course of 40 years, Carl Unger still delights in recalling one of the first passengers on the airplane he and two friends designed and built: "She was wearing nothing but sandals," he says with a laugh.

It was 1965, and Unger, along with fellow Chicago-area corporate pilots Charles Roloff and Robert Liposky, had just finished the 40 hours of test flying the Federal Aviation Administration mandates for homebuilt aircraft. "The FAA drew us a corridor for the 40 hours over some sparsely populated area," Unger says. "Nobody ever saw this airplane." On his first day flying outside the corridor, he landed on a small strip south of Chicago surrounded by thick woods. While taxiing back to take off, he saw three women emerge from the trees, indeed wearing nothing but sandals.

Unger had landed at a nudist colony.

"The tall one waved and I waved back, so they came running out to the airplane," he recalls today with a nod to his wife, who is sitting across the living room and knows the story well. Unger stopped the airplane and the women walked around it. They laughed and said, "It looks like us—it's got nothing on!"

CHRIS MILLER/EAA

Opposite: Look, Ma! No fuselage! Carl Unger has introduced thousands to Breezy flight at airshows, where fans have learned to look for his trademark red vest, goggles and backwards cap.

Before long, dozens of nudists were standing next to the naked airplane. "I remember meeting them and looking them right in the eye. I thought I handled myself pretty good," he says with a wink. After a few minutes, one of the nudists asked if she could go for a ride. Unger was surprised that anyone other than his pilot friends would want to get on the airplane; this was a time long before ultralights, and the airplane looked like nothing else in the sky. But Unger figured, Why not? "Yeah, get on," he said. The woman doubled her wardrobe by donning a pair of goggles, set down a towel, hopped onto the back seat—and Unger flew one of the first of what would be thousands of passengers in the Breezy.

Since that day, the Breezy has become most famous as an airplane that seems tailor-made for giving rides. Shortly after the visit to the nudist colony, Unger, dressed in the tidy red vest, tie, and slacks that would become his trademark, made his first flight to the Experimental Aircraft Association's 1965 fly-in in Rockford, Illinois (now known as EAA AirVenture and held in Oshkosh, Wisconsin). That first year, the airplane was presented with a trophy for the most popular homebuilt, as well as an award for the most unusual instrument panel (it's beneath plexiglass under the pilot's feet). The Breezy, formally called an "RLU-1" for Roloff-Liposky-Unger, was a hit, and people asked how they could catch a ride. "Get on" was Unger's simple reply.

The founder of the EAA and the man who helped usher in the homebuilt movement, Paul Poberezny, recalls those early years, and the decades that followed. "The Breezy has been one of the most popular airplanes [at Oshkosh] over the years, and Carl has given thousands of people rides at his own expense for many years at Oshkosh. I give him a lot of credit for [getting people excited about flying]."

The Breezy was never intended to fill such a role. The three designers all worked for the same corporation, flying twin-engine Beech 18s out of Midway airport in Chicago. Unger was in his 30s. "It was all right flying," Unger says, "but it's not like the basics." The young pilots wanted to build something that would get them back to the fundamental stick-and-rudder flying that had lured them to the skies in the first place.

The first foray "back to basics" came when Roloff built a Benson Gyro-Copter from plans in 1963. He flew it many times, but Unger and Liposky weren't totally enthusiastic. Eventually Roloff crashed the Gyro-Copter, escaping with a few bumps and bruises. Despite the crash, Roloff told the other pilots how much fun it was, sitting out in front of the engine with nothing around you. It was something Unger responded to, as he had always wanted an open-air pusher like those Glenn Curtiss or Lincoln Beechey flew in the early days of aviation. "Let's build something that's safe, where we're sitting out there," Unger said. "*That's* really flying."

In addition to all being pilots, Liposky was an engineer, Roloff was an aircraft inspector, and Unger was an expert welder who had been a helicopter mechanic in the Army. The three figured they had the skills to design and build an airplane on their own.

After some discussions, the trio built a small wire model; then, without any written plans, they started to construct the airplane in the company hangar at Midway. They bought 4130 steel aircraft tubing, just a few pieces at a time, because they never really planned out how much they would need. A friend at the airport gave them a deal on a pair of wings off a wrecked Piper PA-12; many of the parts were donated by friends, or literally scrounged from the trash, including a nose-wheel fork from a Cessna 150.

Their two big purchases were a brand-new 90-horsepower Continental engine for $1,700, and $800 for a radio, which brought the total cost of the airplane to $3,500. After six months of welding and cobbling together parts, the team had a prototype ready. Roloff was chosen to make the first flight, based on the fact that he had had his instructor rating the longest. "Two weeks ahead of time we gave him his wake," Unger says about the party at a local bowling alley. On August 7, 1964, the first flight went flawlessly, with Roloff taking off from Lansing Airport in Michigan. The three took the winter off, then resumed testing the following year. The Breezy was on its way to that first EAA airshow and many others throughout the upper Midwest. Once, when Roloff stopped for gas during an early test flight, the airport manager took a long look at the unusual air-

OPPOSITE: JASON PAUR

craft and remarked, "A little breezy, ain't it?" The name stuck.

When Unger returned home after that first airshow, there was a stack of letters at his house from people asking for brochures and plans. "We never thought anybody would want to ride on it, let alone build one," he says. "We had no plans; we built it out of our heads."

After the rush of requests, the three started to reverse-engineer the Breezy, carefully measuring the original in order to develop a set of plans. One American Airlines captain was so eager to build one that he often stopped by the hangar to help; he ended up with the first set of plans, and the second Breezy ever built.

Since 1965, more than 1,000 sets of plans have been sold. Potential builders "don't know what they're up against, and I warn each one of them," says Unger. "I'll tell them, 'Listen, when you get this thing finished, everywhere you go and stop for fuel, they're going to ask for rides.'

"I love it, but I want them to know what's going to happen," he adds, grinning.

Despite its appearance, the Breezy is not an ultralight. Because of its weight, fuel capacity, and top speed, it falls into the experimental category, like many homebuilt airplanes, and requires registration with the FAA and a pilot's license to fly. And many pilots who have flown a Breezy say that in addition to being fun to fly, the aircraft, because of its open fuselage, is one of the easiest.

COURTESY CARL UNGER

Carl Unger, Charles Roloff, and Robert Liposky (above, from left, in 1965) wanted to build something that would get them back to basic stick-and-rudder flying, a longing shared by others (below).

Matt Hlavac (pronounced le-VACK) flies a Breezy in the San Diego area. Because the airplane flies so slowly (90 mph is fast for a Breezy; most cruise at 60 to 70 mph) and has very little fuselage, Hlavac says it can be forgiving in challenging conditions. "I'm never thinking in the back of my mind, *Oh boy, I've got a big crosswind, it's going to be a handful to land.*"

Of the many Breezys flying, several include their builders' personal touches: There's a biplane Breezy; a four-place Breezy (the original can fit three passengers, with two sitting close together on the rear bench seat); a Breezy on floats; a high-powered, aerobatic Breezy that performed at a handful of airshows. "There's even a guy who built one in South Africa with real leopard skin seats," Unger says, thumbing through one of his many picture albums.

GRANT/DCP, INC.

JASON PAUR

Arnie Zimmerman of Downers Grove, Illinois, has been flying passengers at Oshkosh and other airshows in his Breezy for more than 20 years. He estimates he's given rides to more than 9,000 people. "It's unusual, it's a feeling.... It's an airplane you fly low and slow and you can see everything." Zimmerman says of the Breezy's appeal, "It's a conversation piece." While some people start the ride with white knuckles, "ninety-nine percent of them end with the biggest smile."

Over the years, Zimmerman and Unger have given rides to far more people than they can remember. Kids are always fun, they say, but both have had some memorable famous passengers. Zimmerman recalls one passenger who was put on the back seat and immediately reached forward and began working the controls. "I didn't know he was one of the world's top test pilots," Zimmerman says of cosmonaut Anatoly Artsebarsky. Zimmerman had been told only that he was a visitor from Russia. "He loved it," Zimmerman adds.

Slung beneath a replica Piper PA-12 wing, the Breezy (piloted by Matt Hlavac, near San Diego, above and below) is less confining than a sleigh but, as Santa would agree, no less magical.

MATT HLAVAC

In 1994, on the 25th anniversary of the first moon landing, the Apollo astronauts were honored at Oshkosh. And, being pilots, many of them wanted to experience the Breezy. Charles Duke, the lunar module pilot on Apollo 16, went for a ride, but he says it was his wife who surprised him: "She won't fly with me in a light aircraft, but she really enjoyed the Breezy and was just thrilled to be up and feel the wind and see the visibility you have with the thing." Duke says the Breezy provides "a feeling of freedom that is the attraction of aviation." He says he enjoys the highly technical side of aviation and complex aircraft, "but these real simple ones show you what a little ingenuity and practicality will do. It was just a lot of fun."

Unger recalls all of the Concorde pilots going for rides, several of them more than once. But both pilots remember the less famous passengers as well. Unger fondly recalls an 89-year-old grandmother who took her first airplane ride on a Breezy.

Some of the passengers go on to become aviators themselves—and a number go on to build Breezys. The original flew every year until 1990, when Unger donated it to the EAA museum in Oshkosh; soon after, he found a used Breezy to purchase. Unger's current Breezy was built in 1974 by then-14-year-old Jay Vieaux. The teenager had gone on a ride with Unger; his parents later bought him a set of plans. "I'm sure my parents never thought anything would materialize of it," he says more than 30 years later. But after some welding lessons and a lot of mentoring from Unger himself, Vieaux finished the airplane. He's proud to see Unger still flying it each year at Oshkosh. "It's really good to see that he's still giving rides and keeping people interested in aviation," he says.

Today, Unger is a spry 76 years old. And when he starts talking about flying, a listener might think he had just taken his first ride. His voice rises with excitement as he leans in to the conversation. His eyes widen and he carefully studies your face to make sure you truly understand what an amazing thing it is to travel through the air. When passengers on the Breezy—from astronauts and Concorde pilots to grandmothers and kids on their first rides—walk away from a flight with the same kind of excitement, you have to wonder if they caught it from Unger, or from the little naked airplane.

Resto

Prairie Queen | Fleet Model 8

McCONNELL AIR FORCE BASE in Kansas is named after the McConnell brothers, Fred, Thomas, and Edwin, who gained a measure of fame during World War II. "The flying McConnell brothers," brought up in the pre-war aviation milieu in Wichita, joined the Army Air Corps together, trained together, and served together. Their mother, Anna, pinned on their wings at the completion of their pilot training at Luke Field in Phoenix, an event widely reported in newspapers.

On July 10, 1943, the brothers flew three B-24 Liberators on a 13th Air Force mission from Henderson Field on Guadalcanal, in the Solomon Islands, to Bougainville. On the return trip, Tom and his aircraft and crew were lost in bad weather. Fred went on to fly a total of 61 combat missions in the Pacific theater; Edwin flew 56 missions and was then transferred Stateside.

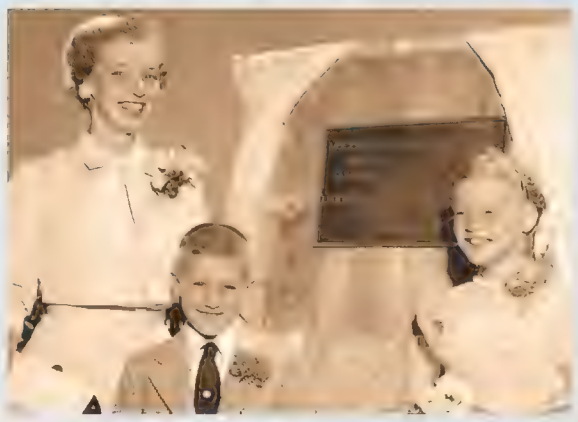
Fred remained in the Army Air Forces after the war, and in October 1945 he was transferred to the Army Air Field in Garden City, Kansas. On October 21, Fred and his wife, Mary Louise, known as Blondie, departed Wichita en route to Garden City in Fred's 1931 blue-and-yellow open-cockpit Fleet Model 8 biplane. In the front cockpit with Blondie were linens for their new house in Garden City. Twenty-five miles west of Wichita, the Fleet hit a power line and crashed. Blondie survived; Fred, however, who, according to the Civil Aeronautics Administration accident report, was not wearing his seat belt, was killed.

In 1954 Blondie and her children, Tommy, Nancy, and Kittie Lou, attended the dedication of McConnell Air Force Base. Kittie Lou was very young when her father was killed, but remembers him and this detail of the dedication: "General H.R. Spicer sent a B-17 to pick us up." Edwin McConnell died in 1997 at the age of 76, and in 1999 the base was re-dedicated to include his name. And that would have been the end of the story had it not been for Jim Bumgarner's aviation maintenance class.

Jim Bumgarner is *all* about airplanes. After flying more than 70 missions as a C-47 engineer during the Korean War, Bumgarner returned to Missouri, where he worked for the Army Air Guard and ran a fixed-base operation at Skyhaven Airport in Warrensburg. When the University of Central Missouri started an aviation program in 1968, he became chief of maintenance and oversaw development of the operation into a program comprising more than 40 aircraft. Students under his supervision maintained the fleet, and when one student casually mentioned that an airplane had been abandoned on his family farm in Kansas, Bumgarner's curiosity was piqued.

He drove over and found a fuselage center section. After some detective work, he found parts of the airplane's empennage hanging in a neighbor's shed, some landing gear parts and a baggage compartment door at a nearby high school, and the fuselage aft of the cockpit serving as an ornamental windmill in the garden of a farmer. (Bumgarner welded a replacement to trade him for the fuselage.) An area ad-

BELOW: COURTESY LEMUEL C. SHATTUCK



Anna McConnell pins wings on her sons (from left to right) Thomas, Edwin, and Fred at the completion of their pilot training in the Army Air Corps (below).

COURTESY KITTIE LOU ENGLISH (3)

Wichita Air Force Base was renamed in honor of the McConnell brothers in 1954; above, Blondie, Tommy, and Kittie Lou attend the dedication ceremony.

Right: Jim Bumgarner, the maestro. Fred McConnell and sister Ruth clown around with the Fleet in 1942 (below).

r a t i o n

jacent to the farm's accident site had over the years become a junk pile, filled with barbed wire, corrugated tin siding, and trash. In Bumgarner's words, "Anything that was airplane, we pulled out of it." A tree at the site had to be felled to free a wingtip it had grown around. The accumulated material was just enough to fill the back of his pickup.

Bumgarner determined the make of the aircraft from the singular construction of the wing ribs. A serial number on the baggage compartment door enabled him to obtain extensive documentation from the Federal Aviation Administration. The airplane was a Fleet Model 8, and its last registered owner was Fred McConnell. A block of 15 serial numbers had been allotted for the model; seven were produced. The only other extant Fleet Model 8 that Bumgarner knows of is in the New York State Museum in Albany.

The restoration started as a blue chalk line snapped on the concrete floor of the hangar. Most of the parts had to be painstakingly reproduced. Bumgarner fashioned the top wing spar, a single piece of laminated wood, 28 feet from tip to tip. One of the few pieces of original equipment is the airplane's Heywood Air Starter. Bumgarner was lucky enough to locate dies to stamp the unique hat section wing ribs. "If I had to do it over again," he says, "I'd start with soft aluminum and send them to be hardened later." To determine the dimensions needed to fabricate the struts, a New York student heading home for vacation was dispatched to the museum in Albany with a camera and tape measure.

During the restoration, Bumgarner discovered that the rear seat belt attachment fittings had been torn out of the fuselage; the accident report was incorrect. "I found it hard to believe that an experienced pilot like Fred would be flying without a seat belt," Bumgarner says. He also has an opinion about the accident: "It was windy that day and he was probably flying low into the setting sun to stay out of the worst of the wind. The Kinner engine has a habit of specking up the windshield with oil from the rocker boxes. Those conditions could make it difficult to see and avoid a wire."

The Fleet came to life in 1995, 11 years after the restoration began, and more than 45 years after it was left for dead on the Kansas prairie. This airplane is not a hangar queen; it's flown regularly to aviation fly-ins. Bumgarner and Kittie Lou are in touch, and Kittie Lou plans to come out in 2008 to meet Bumgarner and the Fleet. She's looking forward to seeing the prairie sky from the best seat in the house—as Blondie did so many years ago.

LEMUEL C. SHATTUCK

GILLES AULIARD

COURTESY JIM BUMGARNER

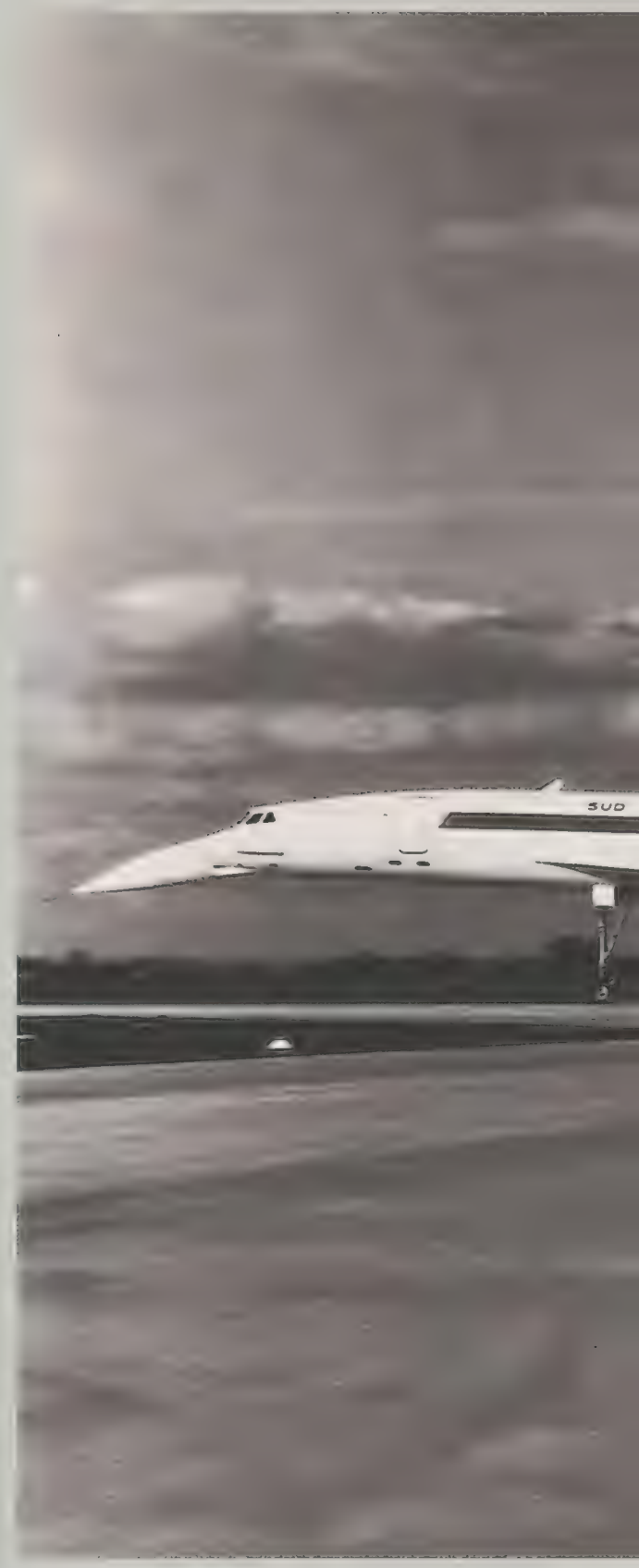
Left: Eleven years after restoration began, the Fleet came to life; it's now a regular at fly-ins throughout the Midwest (above, the Blakesburg, Iowa antique aircraft fly-in).

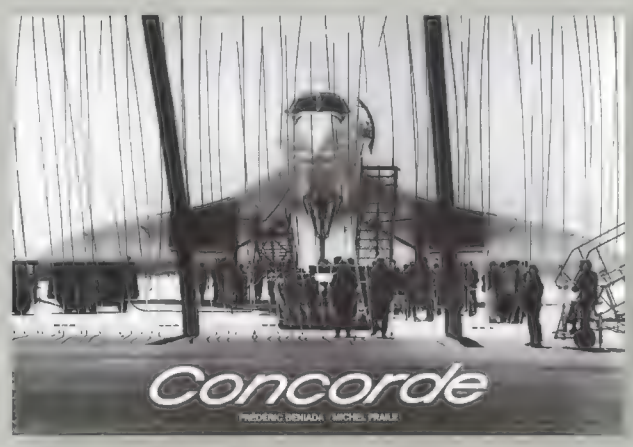
FIND OUT MORE
www.airspacemag.com
READ AN INTERVIEW WITH KITTIE LOU ENGLISH AND AUTHOR LEMUEL SHATTUCK.

Sleeping Beauty

A LAST, LONGING LOOK AT THE CONCORDE.

Photographs from *Concorde* reprinted with permission from Zenith Press.





COLLECTION MUSÉE AIR FRANCE

Requiring 18 hours of maintenance for every hour in the air, Concordes spent most of their lives in hangars. Of particular concern were the lubricant distribution systems of the massive Olympus engines.

AIRBUS

Under the watchful eye of a Gloster Meteor chase airplane, the first French-built prototype, F-WTSS, deploys a drag chute during a test of the aircraft's brakes at the Sud Aviation factory in Toulouse, France.

WHO DOESN'T MISS THE CONCORDE? The loveliest airliner ever built retired in 2003, after 25 years of passenger service, and the airports it frequented haven't been the same. Few of us got the chance to fly on the supersonic jet, but simply seeing it was a memorable experience.

The Concorde can still be seen. Though only 20 prototype and production aircraft were built, 18 are on display at a fortunate group of museums, airports, and factories in Europe, the United States, and Barbados. If you can't make it to one of them, we'd advise taking a look at the recently published *Concorde* (Zenith Press, 2006), a book for those who never tire of admiring the airliner's magnificent lines.

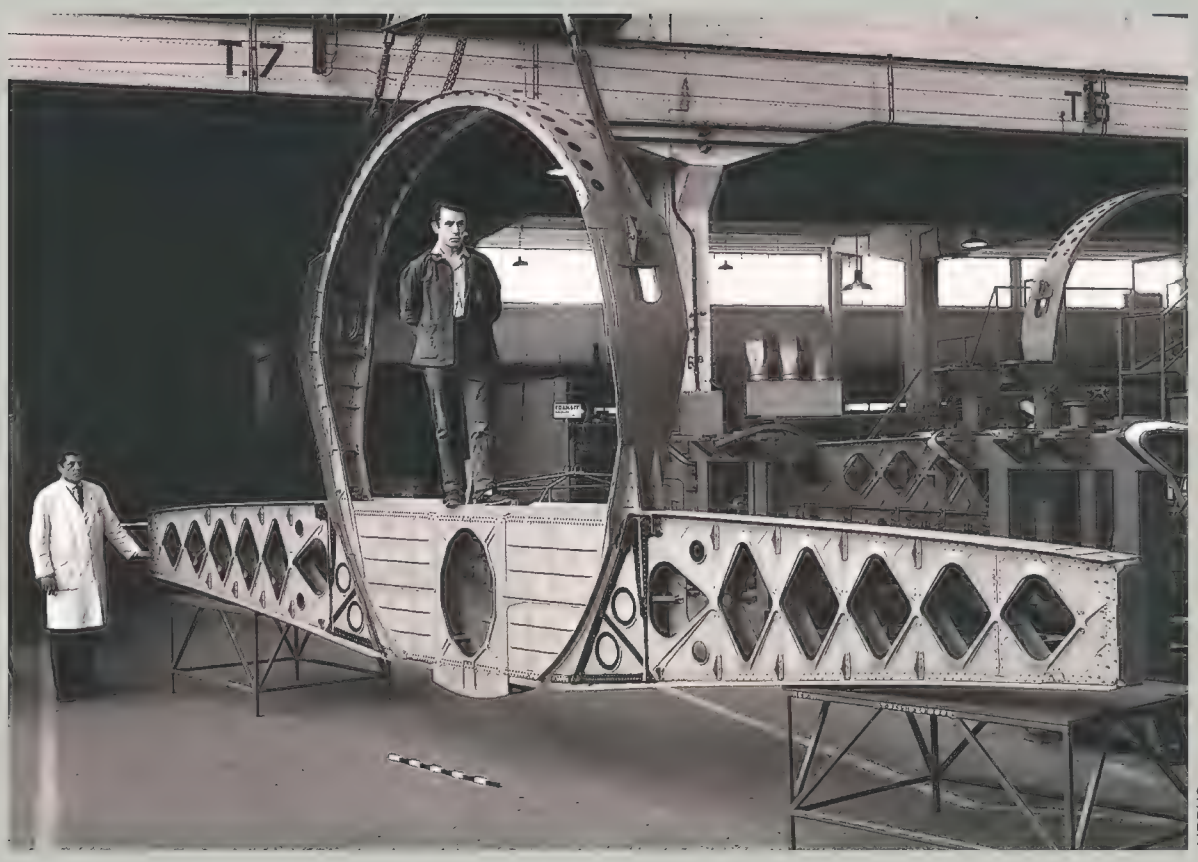
With text by French journalist and pilot Frédéric Beniada and 120 images selected by photo editor Michel Fraile, *Concorde* provides a history of the supersonic transport's career, starting with its joint development in the 1960s by Sud Aviation in France and British Aircraft Corporation in the United Kingdom. A design compromise only made the transport more exquisite. Engineers had considered giving the aircraft a delta wing. The triangular shape is excellent for generating lift and reducing drag at supersonic speeds, but when the airliner takes off, climbs out, maintains a holding pattern, or lands, it flies at subsonic speeds, and at those, the delta wing's lift is insufficient. By gently curving the lines into an ogival shape, like a bullet's nose, engineers gave the Concorde sufficient low-speed lift—and the appearance of a great white bird.

Flying at Mach 2.2, the Concorde could cross the Atlantic in under four hours. Compare that with the doleful seven to eight hours that a conventional jet requires and it's easy to understand why the Concorde will always be the airliner of our dreams.

—The editors

Once-a-year power washes kept the Concorde fleet looking sharp (right).

COLLECTION MUSÉE AIR FRANCE



AIRBUS

Aeronautical sculpture: To connect the Concorde's wing to the fuselage, engineers working on the first production model devised a spectacular framework (left).

On November 12, 1970, just after the death of former French president Charles de Gaulle, test pilot André Turcat flew over Toulouse as an homage to the long-time Concorde advocate (opposite).

Wind tunnel tests of Concorde models (right) aided designers in creating a wing that could generate lift at every point in the airliner's flight profile.

LEFT: ONERA; OPPOSITE: JEAN DIEUZAIDE

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www.airspacemag.com
HOW MANY CONCORDES ARE ON DISPLAY IN THE UNITED STATES?

My Other Car

YOU HEAD OUT THE DOOR and down to the street to catch your ride to work. The aircraft is waiting. The only sound is the low hum of ducted fans at the rear.

Where you'd once expected a pilot, there is instead a panel of blinking lights. To the left and right, more vehicles drop out of the morning sky to pick up your neighbors. You wave a card that opens the door, enters your destination into the flight planner, and debits your account, then spend the quiet, 20-minute commute reading, dozing, or sharing a laugh with your seatmate. The scene sounds like a fantasy because, despite great interest and the effects of "The Jetsons" cartoon on a generation of youth, the promise of affordable, automated flying commuter craft remains unfulfilled.

BY MARK GATLIN

True, there are a plethora of small flying craft around—light sport and ultralights—but there is still no aircraft that, compared to a car, is as easy to operate. Designs for flying cars have been with us for decades, but no drive-fly vehicle designs have ever been submitted to the Federal Aviation Administration for certification.

In recent years, however, U.S. government agencies and private enterprises around the world have been developing the seed technologies that may finally give rise to this new form of aviation. The scenario of replacing cars, buses, and trucks with flying vehicles will be preceded by the introduction of propulsion systems and other technologies involving automated flight.

In the United States, the gurus of flying cars are researchers at NASA's Langley Research Center in Virginia who have recently completed a four-year study of the possibilities of personal air vehicles. While NASA's research funding of such craft is ending, veterans of the program say that much of the technology that is needed to launch the industry is either available in the private sector or

A NASA program that ended in 2005 generated little more than this artist's conception (above) of the perfect easy-to-fly personal air car.

NASA LANGLEY

achievable in the near term.

According to Dennis Bushnell, a NASA chief scientist and member of the Langley team, the first step toward a flying car is to take some of the burden of flying that traditionally fell on pilots and pass it on to computers. Bushnell says the ability to create an autonomous robotic vehicle will be possible "very soon." He observes that the growing use of unmanned aerial vehicles by the U.S. government—including all branches of the military, the Department of Homeland Security, and the National Oceanic and Atmospheric Administration—is providing the technological breakthroughs necessary for personal air vehicles. "The initial personal air vehicle probably won't be inhabited," Bushnell says. "It will be a civilian version of a military UAV to do robotic package delivery."

What would follow fast on the tail of an unmanned pizza delivery pod would be a commuter version: "Think of unmanned aerial vehicles with humans as cargo," Bushnell says. He envisions an air vehicle that can also drive on the ground, yet still costs less than $50,000. "It will not fly high and not very fast—say, 120 knots [138 mph]—and feature a two-passenger climate-controlled cockpit," Bushnell predicts.

The engineer says that at least initially the vehicles will employ super-short takeoff and landing. "You need something that will take off on the 50 to 70 feet of street in front of your house," says Bushnell. The vehicles will have to be affordable and safe. That may rule out rotorcraft, including tilt-rotor designs, Bushnell acknowledges: "They cost much more to own and operate and are inherently less safe."

Even in sparsely populated areas, the vehicles will also have to be quiet. Many personal air vehicle proponents see ducted fans as the solution, since they are quieter and lighter than either propellers or rotors. The progress is quantifiable: In late May the FAA issued an experimental airworthiness certificate for the first vertical-takeoff, hover-capable aircraft with ducted fans.

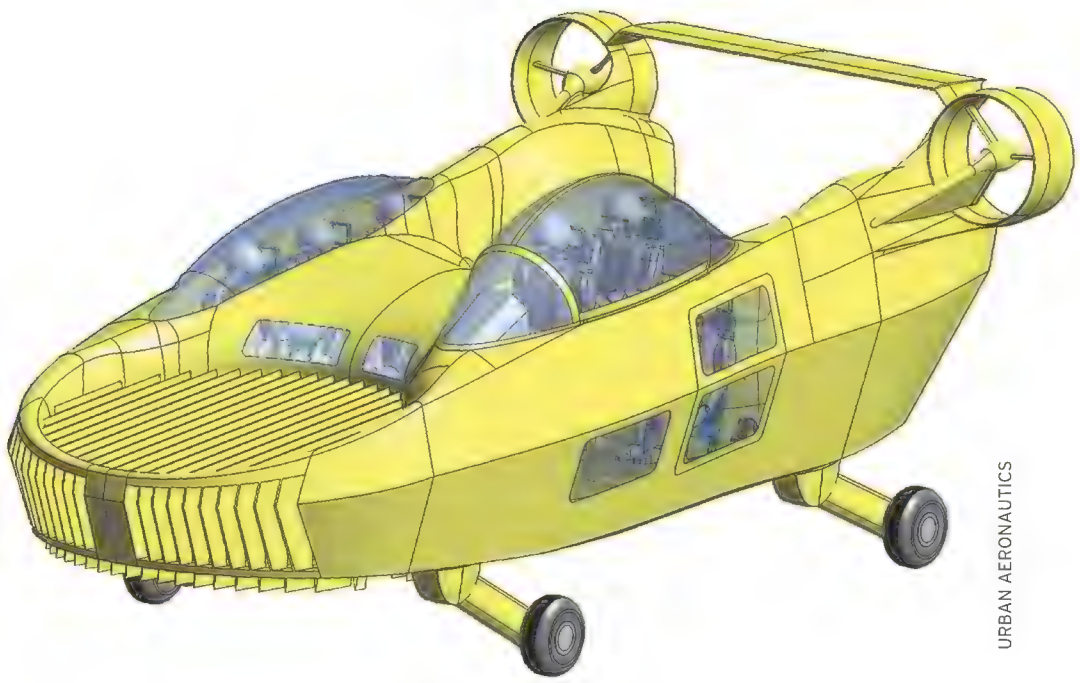
The 65-inch GoldenEye 50 is a winged design that uses a propeller enclosed within a cylindrical body to hover. It was designed by Aurora Flight Sciences Corporation of Manassas, Virginia, under a Department of Defense contract as a platform

Is a Podcopter

BUMPER STICKER IN THE YEAR 2015? 2025? EVER?

Modern designs for commuter aircraft are inspired by the twin ducted-fan rotors that powered the Piasecki Flying Jeep during the 1950s and 1960s.

PIASECKI CORP.



URBAN AERONAUTICS

Is this seat taken? The X-Hawk flying bus (left), designed in Israel, would carry 10 commuters at a time and be stable enough to load and offload passengers while hovering.

to carry battlefield sensors. It's just a matter of time, the company is gambling, before there will be a need for larger aircraft using the same technology. The GoldenEye 50 was designed as a technology development platform for the GoldenEye 80, a 150-pound ducted-fan aircraft.

Several private ventures are developing ducted-fan vehicles capable of vertical flight, but few are as far along as Israel's Urban Aeronautics. The company's X-Hawk, inspired by the Piasecki Flying Jeep of the 1950s and '60s, uses a U.S.-patented control system. The airflow created by the ducted-fan engine is directed by two arrays of thin-blade vanes; one array at the inlet, the other at the outlet of the duct.

While the first X-Hawks will be military and rescue versions, Urban Aero's marketing director, Janina Frankel-Yoeli, says that future models "will fulfill the role of a communal aerial vehicle, such as a schoolbus or commuter shuttle." Company officails say the first full-scale prototype may make its first test flights in two and a half years.

Clearing the engineering hurdles is just the first step in creating a flying car. That car needs a person on board who acts more like a passenger than a pilot. That means pairing everyday folks with trustworthy onboard computers.

The NASA team at Langley developed two systems intended to develop sentient vehicles that could offer, according to a NASA report, "fully autonomous flight" for a lone pilot in nearly all weather "with confidence and relative ease."

In the report, the pilot-craft relationship is compared to more familiar partnerships: "The pilot guides the personal air vehicle with the control stick and the [onboard programming, reacting to the pilot's actions] negotiates turbulent air as best it can, just as a rider guides through the reins and the horse negotiates rough terrain." If the pilot is distracted or makes a mistake, the computer vibrates the stick to alert him. If there is still no response, the system will divert the craft to the nearest airfield.

Andrew Hahn, an aerospace engineer at Langley who researched personal air vehicles, is hopeful but guarded about automated systems. "The automation will undoubtedly get better," he says. "When the automation gets really good, we may allow the automation to fly without people, over lightly populated areas, but I don't see high-energy UAVs flying fully autonomously in heavy traffic and over cities for a long, long time."

A smart vehicle's intelligence is determined by more than onboard technology. Someone or something has to keep vehicles from colliding. In airspace with many small personal air vehicles zipping around, a workable system may well require a totally automatic, redundant navigation and air traf-

The initial personal air vehicle probably won't be inhabited. It will be...a UAV to do robotic package delivery.

–NASA LANGLEY CHIEF SCIENTIST DENNIS BUSHNELL

A future CarterCopter product, depicted at right near a fictional gas pump, will use wings to fly, rotors to hover, and conventional diesel as fuel. Just fill 'er up and fly.

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The YES Zulu is on display in the Time Galleries at the Royal Observatory in Greenwich.

This professional time piece is programmed for over 500 cities worldwide, automatically adjusts for Daylight Saving Time and can be set by longitude, latitude and time zone. Having this time info on your wrist offers practical time management applications not found in any other time piece. Flying changes a lot after dark and with YES you can plan to be safely on the ground before sunset. The cleverly designed visual display of day and night with the 24-hour hand offers an intuitive sense of where you are in the cycle of day and night. When traveling the display can help you to plan your sleeping cycle to overcome jetlag quicker. For those with business and family in faraway land, local time can be displayed at the push of a button. Astronomers use the YES watch to plan the best times for viewing the universe. Photographers use it to plan when to catch the golden light of dusk and dawn.

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"I fly in tactical situations all over the world, mostly at night and on Night Vision Goggles. When relying on NVG's to help land a tactical airlifter on a short runway, in training, or in combat, it's critical to know the sun and moon data, particularly the moon illumination, that the YES Zulu watch offers. That's why I got one, and I have not been disappointed."

Lt Col Tim Harris, USAFR

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You might ask yourself, 'Am I ready to buy a ticket on a pilotless aircraft?'

–FAA SPOKESMAN LES DORR

fic control system. Bushnell points to progress with some of the flight software the military has designed for unmanned aerial operations. Building on these advances, he says, a robust, automated civilian system could be established within a decade.

Others are not so quick to abandon the human element. "Fully automated air traffic management is still many years off—perhaps more than 50," says NASA's Mark Ballin, a Langley researcher of aviation operations and a member of an interagency team tasked with designing the country's Next Generation Air Transportation System, commonly called NextGen.

The team is seeking to upgrade the air traffic control system to handle the two- to three-fold increase in flights and passengers expected by 2025. But NextGen will still need human controllers, and some within the team say that will never change.

The most important question of human involvement revolves around consumer preference and manufacturer courage. "From the manufacturers' standpoint, aircraft are low-volume and high-liability, which quite frankly scares them to death," notes Hahn. "From the average person's viewpoint, they are unobtainable, dangerous, hard-to-use toys that are really annoying. As long as both parties believe this, the answer [to when personal air vehicles will fly] will be 'never.' "

FAA spokesman Les Dorr says that technology development "will be driven by market forces and the ability to comply with FAA safety regulations. You might ask yourself 'Am I ready to buy a ticket on a pilotless aircraft?' "

When the Langley team disbanded in 2005, NASA's direct personal air vehicle research ended, but the dream continues. The space agency, working through the Comparative Aircraft Flight Efficiency Foundation, in August awarded $250,000 in prize money for its PAV Challenge for the design of a two- or three-seat vehicle with an 800-mile range and ability to use a short runway.

The victor was Vance Turner, owner of a short-wing Pipistrel Virus, a lightweight sport aircraft built in Slovenia. The craft can go 170 mph and gets 50 miles to the gallon.

The challenge is the first of five annual competitions being held through 2011. When and if consumers ever trust flying cars enough to want to buy one, the dreamers want to be ready.

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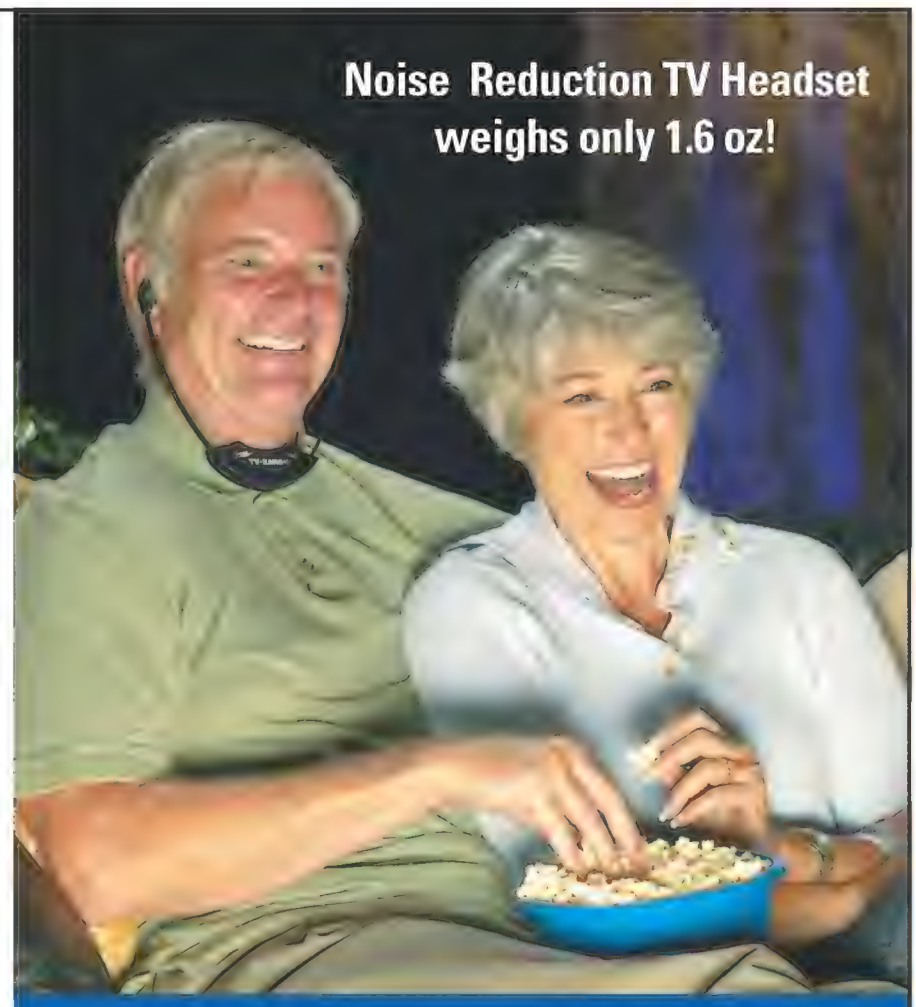

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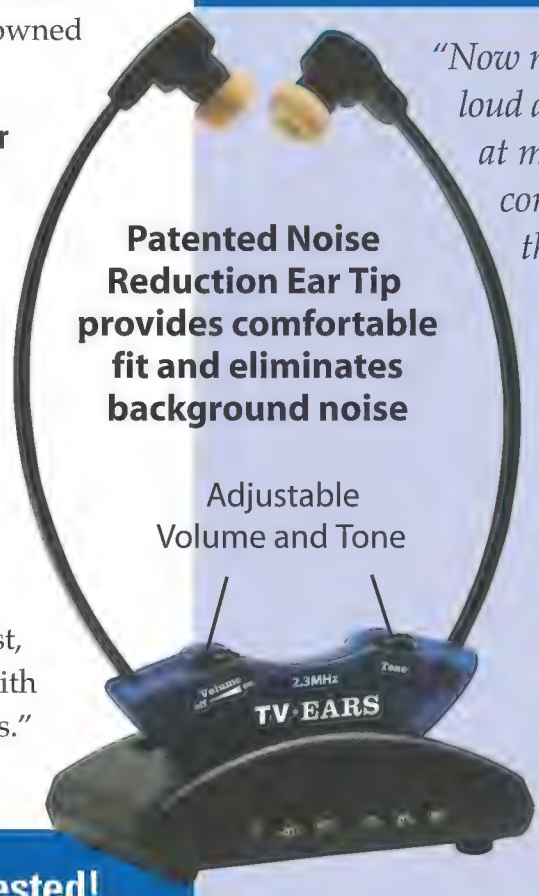

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Sightings

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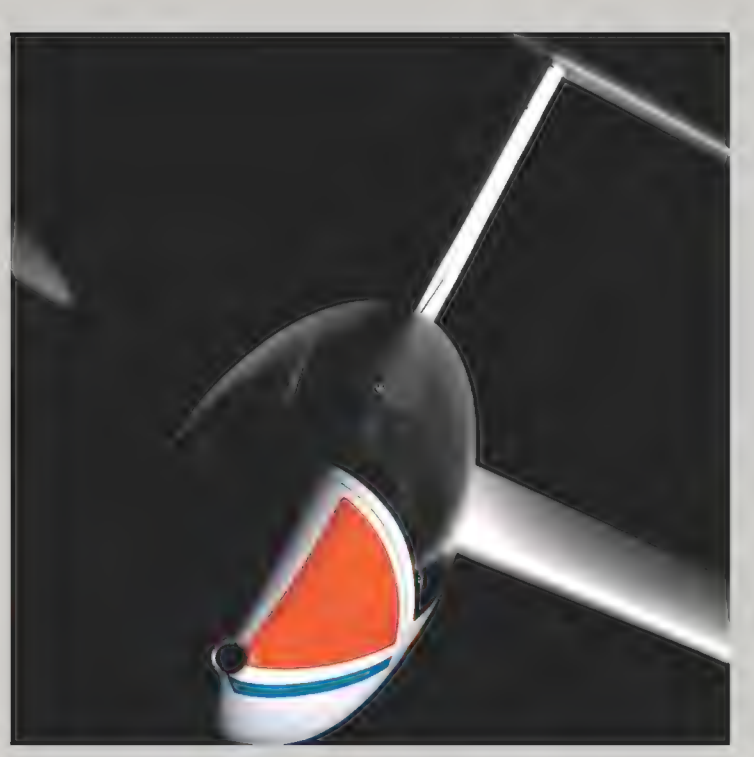
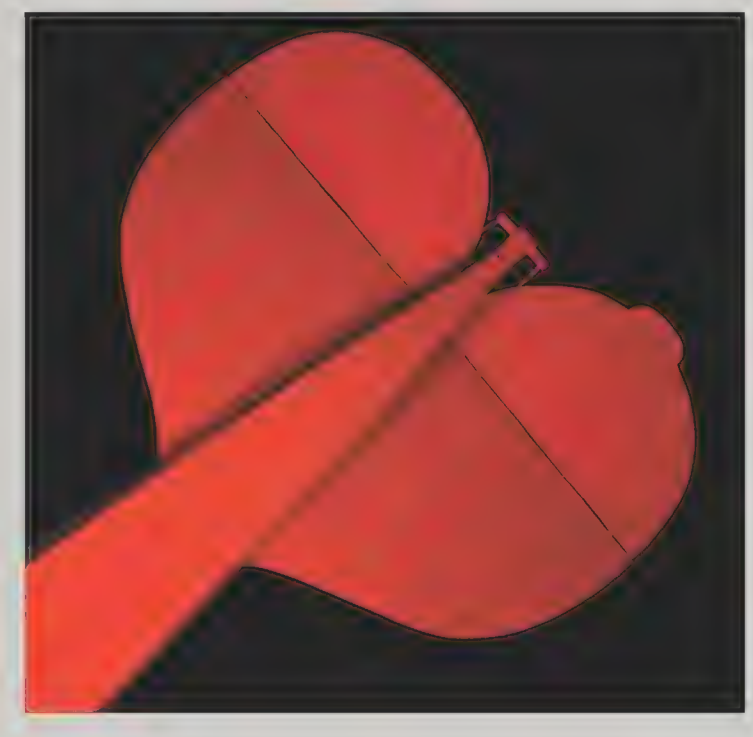
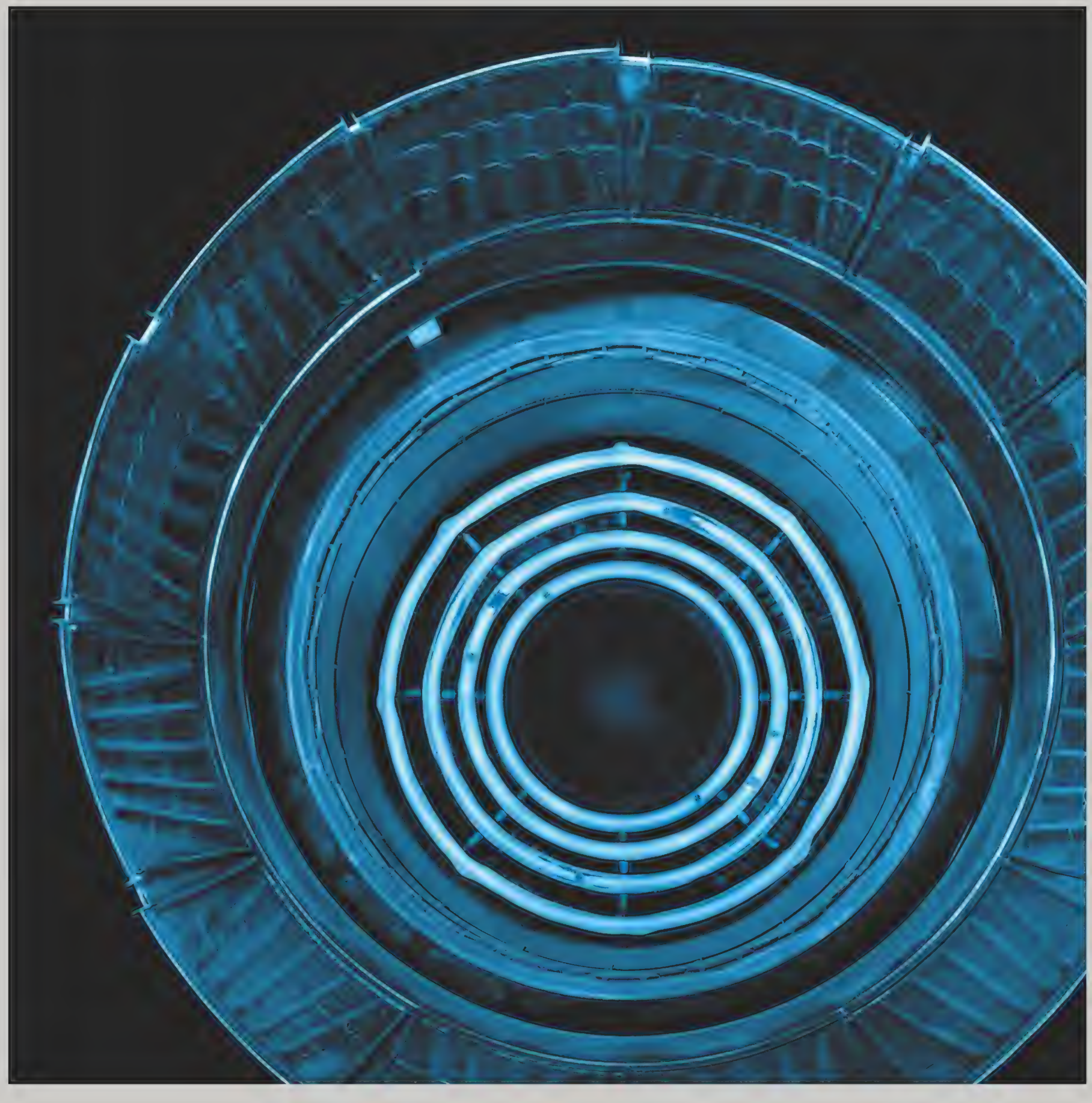




STALKING THE NATIONAL Air and Space Museum displays after hours, Museum photographer Carolyn Russo has the time and solitude to see the details and personalities of aircraft that visitors may miss during their tours. "It seemed that my best shots came late at night," Russo says. "I'm not sure if it was because I was so tired and started to see differently, or that's when the aircraft came alive and revealed themselves."

Approaching the objects as if making portraits of people, Russo uses the play of light and shadow to capture different qualities of an airplane, as she did in the photograph of the sleek canopy of a German Grob 102 Standard Astir II sailplane (right, top). On the retro-rocket pack of the Mercury capsule *Freedom 7*, she focused on the distinct black and white patterns (right, center). Other times, less prominent elements appear, such as the heart-shape tail of the homebuilt Wittman midget racer *Chief Oshkosh/Buster* (right, bottom).

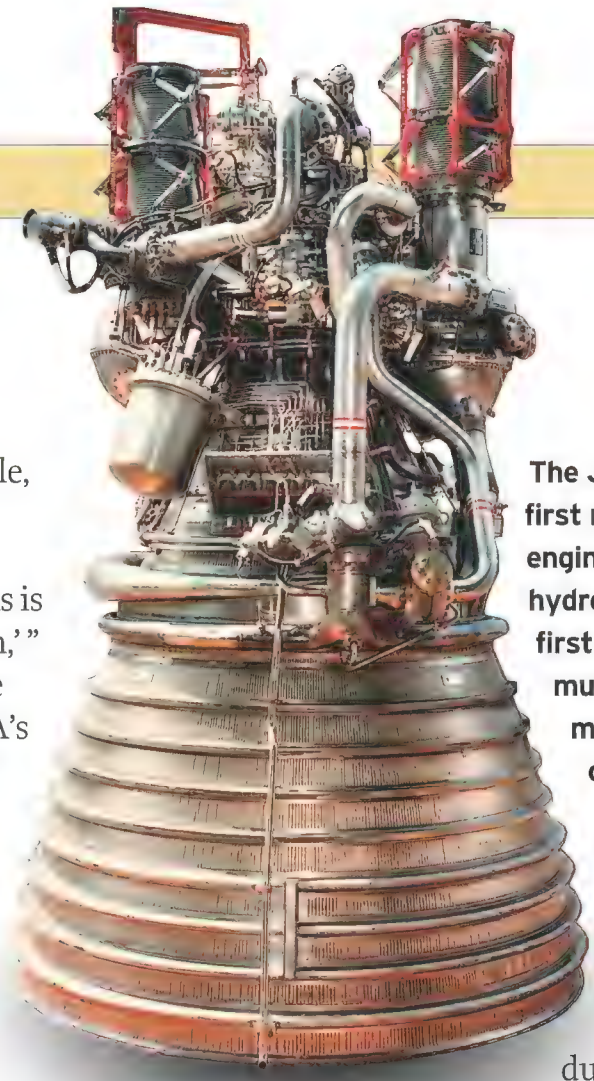
Unconventional views of airplanes lead to new appreciation of their capabilities. The exhaust nozzle of the SR-71 Blackbird (opposite) is circled with four afterburner fuel rings, which increase the power of each engine to 32,000 pounds of thrust. Russo's latest book of photographs, *In Plane View: Abstractions of Flight*, its cover graced by a blurred image of a MiG-21F's rudder and horizontal stabilizer (above), is available from powerHouse Books. An exhibit showcasing the book will open at the Museum in March.



Blast From the Past

NASA'S LATEST manned venture—the post-space shuttle program Constellation, which is intended to fly astronauts to the International Space Station and eventually to the moon—borrows heavily from technology that powered the upper stages of Saturn rockets during the Apollo program more than four decades ago.

Two considerations, time and money, are driving the decision to modify the old J-2 engine for use on Constellation's Ares rocket. The last man-rated engine NASA developed, the space shuttle main engine (SSME), took 12 years; work on the J-2X should take seven. And because the J-2X is a single-use engine, it will be cheaper to build than the SSME, which was designed for reuse and required parts that were more durable, and therefore more expensive.



The J-2 was both the first man-rated rocket engine to use liquid hydrogen fuel and the first to be restarted multiple times during a mission. Early concept studies envisioned using five as the main engines for the space shuttle.

"One of our mantras is 'Safe, simple, and soon,' " says Mike Kynard, the J-2X manager at NASA's Marshall Space Flight Center in Huntsville, Alabama. "We're drawing on these proven technologies and are very wary about adding complication. We're confident it's going to work out of the box."

That confidence comes from NASA's long history with the J-2, which North American Aviation's Rocketdyne Division began working on in the fall of 1960. The engine logged a perfect track record through the 15 manned flights of the Apollo program, which ended with the Apollo-Soyuz rendezvous in 1975. On the Saturn V, five engines flew in a cluster on the second stage and one on the third stage. On the smaller Saturn 1B, used for Apollo 7, Skylab, and Apollo-Soyuz, one engine flew on the second stage.

Although the J-2X will look very much like its predecessor, it has two big advantages. Its thrust will be much greater (294,000 pounds vs. 230,000) and its fuel efficiency will be better. Its specific impulse, a measurement of the latter, is 448 seconds, meaning that for every pound of fuel burned per second, the engine gets 448 pounds of thrust. The J-2's specific impulse was 425.

"That's pretty sporty territory," says John Vilja, J-2X program manager at Pratt & Whitney Rocketdyne. "It's a higher-performing machine and has a lot more margin" due to improvements to its turbopumps, combustion chamber, and nozzle. The J-2X's longer nozzle, made of carbon composite, makes the engine four feet taller than its 11-foot predecessor. A solid-rocket engine will power Ares' first stage.

The yet-to-be-built J-2X, shown as an engineering drawing, is scheduled to have its first full test in early April 2010.

The vehicle will make its first unmanned flight in the summer of 2013, and by then the look of the J-2X may well have changed. Rocketdyne is to deliver eight test engines under a $1.2 billion contract with NASA announced in February 2006. To ensure nothing might be overlooked in modifying an engine that was last made in 1972, Rocketdyne summoned the experts to its Canoga Park, California headquarters.

"The first week under contract, we pulled in a roomful of guys who had put together the J-2—the graybeards, the wise owls—and let them reminisce about building the engine," says Vilja. "We got the former program manager, chief engineer, all the heavyweights from that era. We had about 25 people, and some of them have stayed with us through redesign. We're lucky that a lot of them still live in the area. Building rocket engines must be good for longevity."

That goes for both the builders and their machines.

PAUL HOVERSTEN

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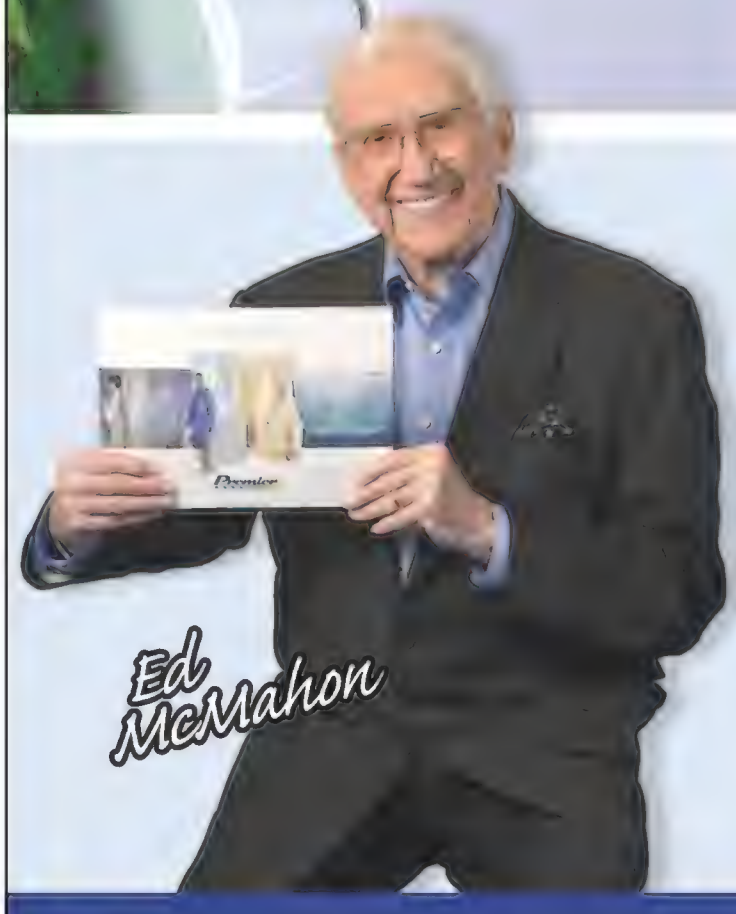

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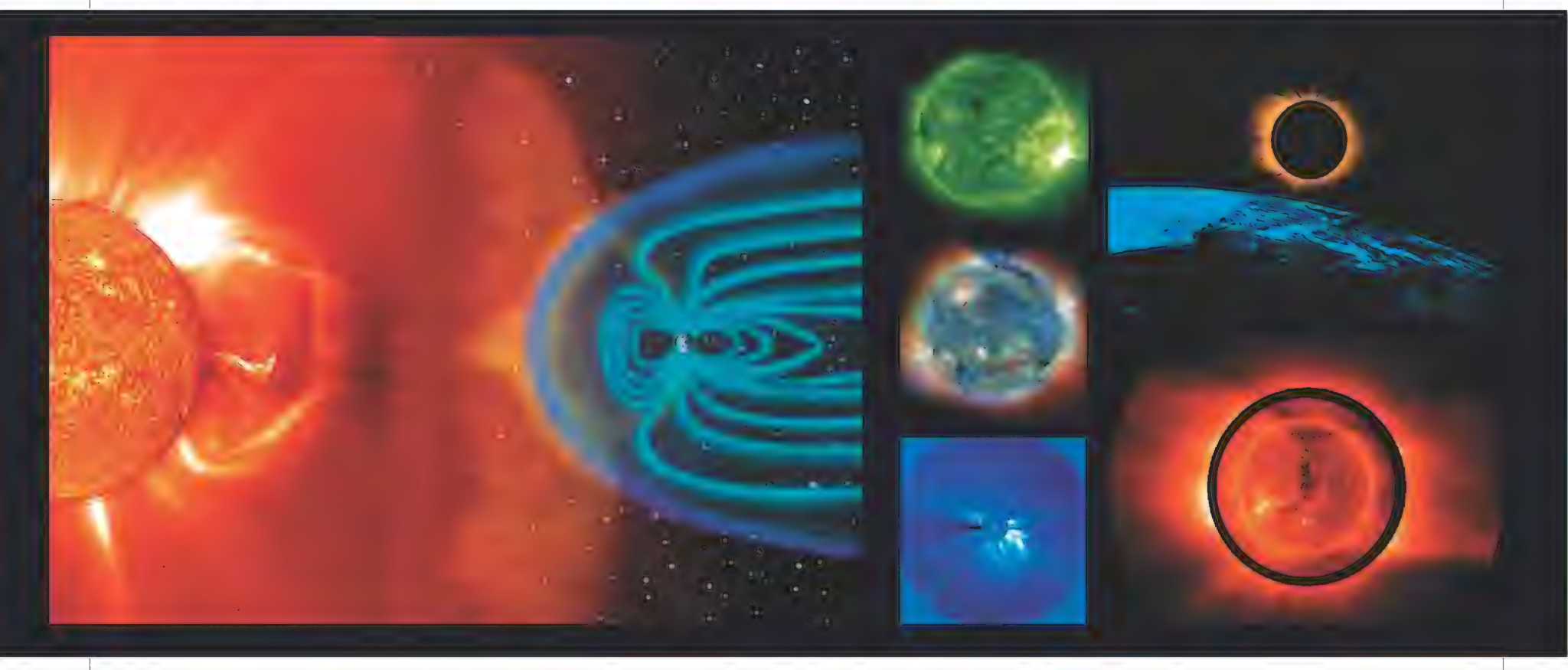


The Solar and Heliospheric Observatory has been documenting the workings of the sun since its launch in 1995. To see more images, visit *sohowww.nascom.nasa.gov*.

SOHO; ESA; NASA

The Sun Kings: The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began

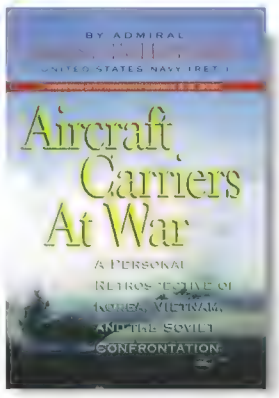
by Stuart Clark. Princeton University Press, 2007. 224 pp., $24.95.

The sun's influence on life on Earth is obvious today. But only a century ago, the effect of sunlight and solar cycles on our planet aroused controversy. In *The Sun Kings*, Stuart Clark brilliantly tells the story of the scientists, including English astronomer Richard Carrington, who over a period of two centuries were able to put together the series of observations necessary to prove the sun's power (for example, through the effects of solar flares on climate and radio communications).

As a scientist, I was particularly struck by the forceful personalities that Clark covers and the politics that they engaged in. You'd like to think that scientists today would behave better, but the scientific process is the same now as it was then, and they inevitably bring their biases into scientific debates. The one thing that has seemed to change is how scientific facts are presented. Too often we're spoon-fed scientific theories as sound bites, such as "An asteroid killed the dinosaurs" or "The universe is expanding." What we don't hear about is the thinking and effort that lead to such one-liners. More importantly, we don't often hear about the controversies behind these statements.

Occasionally, Clark's descriptions are a bit wordy, but I enjoyed his narration so much that I found myself trying to get through the background passages as quickly as possible to get back to the storytelling. *The Sun Kings* is a must for anyone who might wonder why there is a debate today over such things as global warming and stem cell research.

BOB CRADDOCK IS A GEOLOGIST AT THE NATIONAL AIR AND SPACE MUSEUM.



Aircraft Carriers at War: A Personal Retrospective of Korea, Vietnam, and the Soviet Confrontation

by Admiral James L. Holloway III, U.S. Navy (ret.). Naval Institute Press, 2007. 352 pp., $34.95.

Admiral James L. Holloway III's self-effacing account of his brilliant naval career is a canvas on which he portrays the development of aircraft carrier warfare. Moving as swiftly as a catapult launch, Holloway takes the reader along as he progresses from being a green fighter pilot in the Korean War to commanding multiple task forces in the waters off Vietnam to the peak of his profession: chief of naval operations.

Holloway's descriptions of his many combat missions are both compelling and satisfying. He details everything from takeoff times and the wind speed across the deck to flap settings, climb speeds, and the effect of enemy anti-aircraft fire. In less sure hands, so much information might be overwhelming. Instead, Holloway's battle descriptions are gripping, whether he is recounting a bomb run over Vietnam or an argument among the joint chiefs in the Pentagon.

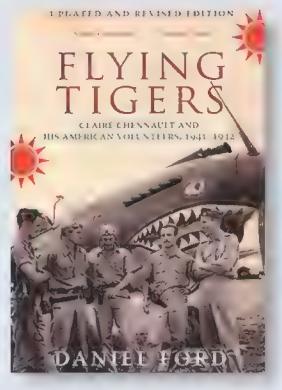
The author is candid on the hazards of carrier operations, and one must admire him and his colleagues for persevering despite appalling losses. Holloway is at his best

The Last of the Combat B-17 Drivers

by Colonel Harold D. Weekley, U.S. Air Force (ret.), and James B. Zazas. Flying Fortress International, 2006. 334 pp., $24.95.

The author gives readers a vivid rendering of what it's like in the cockpit of a Boeing B-17 Flying Fortress.

Flying Tigers: Claire Chennault and His American Volunteers, 1941-1942



by Daniel Ford. Harper Collins/Smithsonian Books, 2007. 384 pp., $15.95.

Air & Space contributing editor Daniel Ford has updated his account of the American Volunteer Group pilots with recent interviews of U.S. veterans, as well as the recollections of Japanese and New Zealand airmen.

Dictatorship of the Air: Aviation Culture and the Fate of Modern Russia

by Scott W. Palmer. Cambridge University Press, 2006. 307 pp., $40.

The author, a specialist in modern Russian culture and technology, details the history of Russian aviation, beginning in 1909.

U.S. Air Force Aviation

compiled by Dennis R. Jenkins. Specialty Press, 2007. 120 pp., $19.95.

U.S. Air Force photographers document all aspects of Air Force flight, including combat operations in Afghanistan and Iraq and Red Flag training exercises in Nevada.

Latin American Air Wars and Aircraft 1912-1969

by Dan Hagedorn. Hikoki, 2006. 175 pp., $59.95.

National Air and Space Museum archivist Dan Hagedorn takes a look at military aviation history south of the border.

in assessing his shipmates, naming with pride and affection those who did well and leaving anonymous those who did not. In a similar way, he tips his four-star admiral's hat to the U.S. Navy's non-commissioned and enlisted personnel, recognizing their vital importance.

Any service deserves to have its best and most experienced members emerge as leaders. The Navy is fortunate that Holloway lived through the many dangers he experienced so that when he was at the very top rung of his profession, he could apply what he had learned. In doing so, he shaped today's Navy in his image. If you are not a carrier advocate now, this book will make you one.

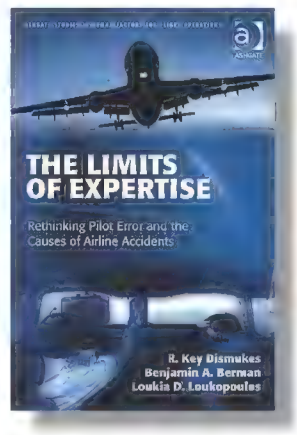
FORMER DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM AND THE FOUNDER OF *AIR & SPACE/SMITHSONIAN*, WALTER J. BOYNE HAS WRITTEN MORE THAN 50 BOOKS.

The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents

by R. Key Dismukes, Benjamin A. Berman, and Loukia D. Loukopoulos. Ashgate, 2007. 352 pp., $39.95.

Some years ago, a travel-magazine editor asked me to write an exposé of a scandal: Most airline accidents are apparently caused by "pilot error." How could the skies be filled with so many incompetent pros, he wondered?

I spent weeks interviewing pilots and aviation safety experts and ultimately wrote that pilot error is only one link in the causal chain that leads to any aircraft accident, and that the phenomenon "pilot error" is misunderstood and often inevitable.



My article was never published. It wasn't what the editor wanted to hear. Pilot error was too complex, too indeterminate, too puzzling.

That's still true. In fact, *The Limits of Expertise* takes that position a substantial leap further: The book asks why brow-slappingly dumb pilot error afflicts intelligent, highly experienced, famously cautious pilots without regard for their flight hours, past careers, and spotless records.

Be aware that this is a textbook, not beach reading. Nobody will use it as the basis of a fireballs-in-the-sky Discovery Channel docudrama. The authors did not choose the accidents they discuss for their drama

>>> Fun Stuff <<<

Air Hogs Reflex Micro Helicopter by Tyco, $59.99.
Dragonfly by Wowwee, *www.wowwee.com*, $49.99.

The Dragonfly and the Reflex are the latest and most innovative of the new breed of remote-controlled featherweight aerial vehicles. The Dragonfly propels itself by flapping its four wings in a creepy, life-like manner, while the self-righting Reflex uses two counter-rotating blades. Though each is made of foam durable enough to survive standard-issue whumps and thwacks, manufacturers have thrown in spare wings and rotors.

SAM GOLDBERG

Having both machines in one's possession begs for the re-creation of a Japanese monster movie scenario: giant robotic insect versus valiant helicopter defender, with the fate of Tokyo hanging in the balance. But because neither flier is worth a lick in even the slightest breeze, such a battle requires conditions found only in a local planetarium. This would be future Tokyo: protectively domed and climate-controlled.

It's quickly evident that neither toy offers the virtue of precision flying, though the Reflex takes off and lands impressively. It's even powerful enough to medevac an action figure crammed M*A*S*H-style into its skids (surely the toy helicopter Holy Grail). The Dragonfly failed to lift even a penny, but its glowing LED eyes penetrate the soul in a way that would reduce Mothra to a giggling little girl-larva.

As for the battle, I spent much of my time huddled over the Reflex, twiddling with a knob that corrects for over-rotation and trying desperately to make the helicopter move forward or backward. During that time, my opponent repeatedly used the Dragonfly to buzz my hunched-over command-and-control center.

After three fly-and-recharge cycles (about 10 minutes of play and 20 minutes of juice for each), we'd given up on a hoped-for mid-air joust. On the strength of easiness to fly, the Dragonfly had claimed Tokyo, its citizens enslaved and left to ponder if a more maneuverable chopper squadron might have saved them.

SAM GOLDBERG DEVELOPS EXHIBITS FOR SEATTLE'S PACIFIC SCIENCE CENTER.

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or because they aligned nicely with any preconceptions. *The Limits of Expertise* simply examines the 19 serious accidents suffered by major U.S. air carriers between 1991 and 2000 in which the National Transportation Safety Board cited crew error as playing a central role. So you'll find everything from a runway overrun that resulted in a single broken leg during evacuation to far more catastrophic occurrences—all described in the same cool, analytical terms.

Ultimately, the authors' analyses reveal that you can come up with a plausible reason for every mental failing of expert pilots, but that there simply may be no defense against the circumstances that at times hinder the brain's ability to process information thoroughly. Pilot error is often the manifestation of systems failures and design mistakes, and perfection in both cockpit design and crew procedures is the final defense against it.

As worthy a goal as that is, it will never be attained.

STEPHAN WILKINSON IS AN *AIR & SPACE* CONTRIBUTING EDITOR.

Paper Pilot: The Paper Airplane Pilot's Manual

by Staff Sergeant Benjamin Haynes. Universe, 2007. 144 pp., $25.

Subject is a 46-year-old Caucasian male suffering from short attention span. Subject admits to building "way too many" plastic airplane models "and poorly" before teenhood. Subject is tasked with building three paper airplanes in ascending order of complexity.

Subject starts with traditional paper airplane, described in Octave Chanute's *Progress in Flying Machines*, published in 1894. Subject folds one sheet of used typing paper in half lengthwise and makes six folds on each side of designated nose.

Assembly time: 01:06.

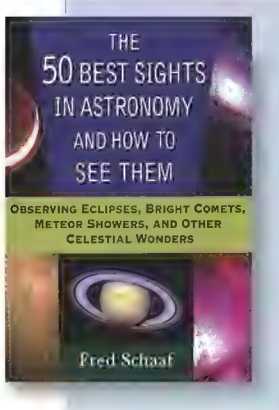
Having been berated by teacher for throwing similar airplane at Brian Nash during fifth-grade English, subject gently tosses airplane toward two-year-old female feline. Feline expresses brief interest.

Next: Subject begins to assemble a B-2 Spirit flying-wing bomber, one of

***Paper Pilot* offers planform views of military aircraft past and present.**

24 punchout paper airplanes in *Paper Pilot: The Paper Airplane Pilot's Manual.* Subject briefly reviews instructional pictograms. Subject carefully removes parts stamped in pages, makes appropriate folds. Assembly delayed by glue requirement. Subject finally

>>> At a Glance <<<



The 50 Best Sights in Astronomy and How to See Them

by Fred Schaaf. John Wiley & Sons, 2007. 280 pp., $19.95.

A guide to viewing everything from the Northern Lights to orbiting satellites.

Earth From Space

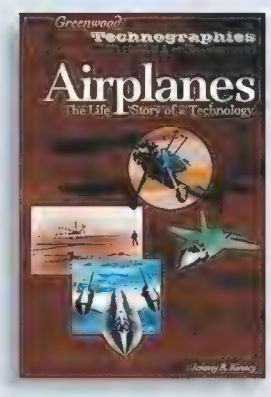
by Andrew K. Johnston. Firefly, 2007. 272 pp., $29.95.

The author, a geographer at the National Air and Space Museum's Center for Earth and Planetary Studies, has assembled hundreds of stunning satellite images.

Airplanes: The Life Story of Technology

by Jeremy R. Kinney. Greenwood Press, 2006. 184 pp., $45.

National Air and Space Museum curator Jeremy R. Kinney has written an informative work on the evolution of the airplane.



The Lunar Exploration Scrapbook

by Robert Godwin. Apogee, 2007. 219 pp., $28.

A fun book full of illustrations on a plethora of moon vehicles.

Innovative Safety Technology

Are you missing the luxury of warm, relaxing baths? Well, grab your towel!

By John Fleming

For many of us, nothing is more relaxing than a long, luxurious bath. Unfortunately, because of safety concerns, many people, particularly older people, have to forego this simple pleasure. Sure, you can spend big bucks to remodel your bathroom to provide a bathtub you can use, but who wants to do that? Now there's a better way, and it lets you use the bath that's in your home today.

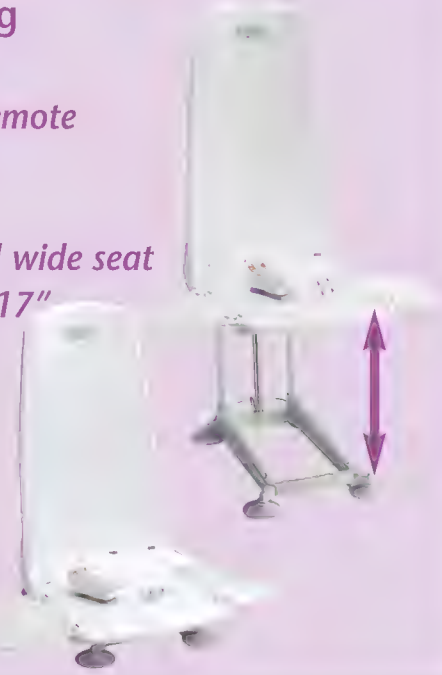
If you or a loved one has given up bathing because of age, mobility or safety concerns, the Archimedes Bath Lift is the answer. It is so simple, you'll wonder why no one thought of it earlier. The battery-operated "chair" safely and steadily lowers you to the bottom of the tub, and when you're done bathing, it gently raises you back to the top of the tub assuring a comfortable and safe exit from the tub. The remote is fully waterproof, so your bath won't be a "shocking" experience.

This innovative chair recharges overnight (don't worry, if there's not enough power stored for a full lower/raise cycle, it will not operate), features an easy-to-use hand control, and is designed for comfort and support. It's lightweight (less than 25 pounds assembled), and easily portable. It features a wide seat and high backrest for maximum comfort and support.

Rediscover the simple pleasure of a warm, relaxing bath with our exclusive home trial. Try the Archimedes Bath Lift for up to 90 days, and if you are not completely satisfied, simply return it for a refund of the product purchase price. Call today.

Enjoy your bath again without the risk of slipping

- *Charges overnight*
- *Fully waterproof remote*
- *Battery operated*
- *Portable*
- *High backrest, and wide seat*
- *Chair raises up to 17" and lowers to 3"– or anywhere in between*
- *Transfer flaps for added stability*



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Reviews & Previews

locates glue and applies.

Assembly time: 14:31.

Following glue-drying period, subject launches model at feline. Model lands in front of feline. Feline stares, sniffs. Loses interest.

Next: Subject attempts assembly of *Paper Pilot*'s World War II-era P-38 Lightning; subject discovers sophisticated model requires too much assembly. Subject grows distracted, tosses jingly ball at feline.

Assembly time: N/A.

Subject pages through *Paper Pilot*, reads brief descriptions of each classic warbird, enjoys vintage photographs and drawings. Subject remembers memorizing their stories during tween years, before life grew complex. Subject continues reading tips for building and flying paper models. Subject attempts second trial flight with completed B-2. Airplane sails over perplexed feline's head. Feline gives chase.

Conclusion: *Paper Pilot* bemuses and amuses feline and happily transports subject back to an age of 10 years.

PHIL SCOTT IS THE AUTHOR OF *HEMINGWAY'S HURRICANE* (McGRAW-HILL, 2006).

>>> Season's Greetings <<<

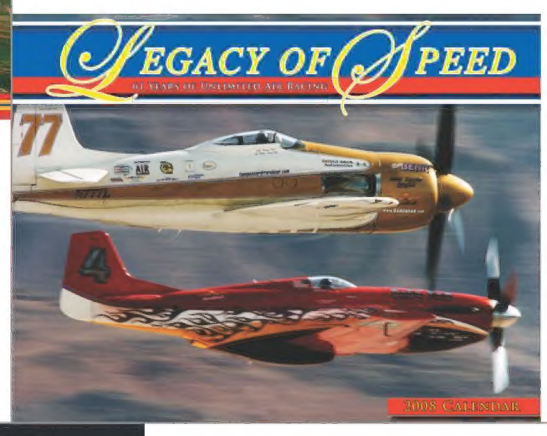
Artist Joe Jones has created a line of greeting cards with aviation themes for all occasions. To order, visit *www.airmail-greetings.com* or call (303) 377-0121.

>>> Calendar Roundup <<<

The new year looks to be a very good one for aviation calendars, especially if you fancy military aircraft: From World War II's P-51 Mustang to the stealthy B-2 Spirit bomber, warbirds galore look their centerfold best. All calendars are available at *www.historicaviation.com* or by calling (800) 225-5575.

Ghosts: The Great War

Photographs by Philip Makanna. $14.99. Also available at *www.ghosts.com*.



Legacy of Speed

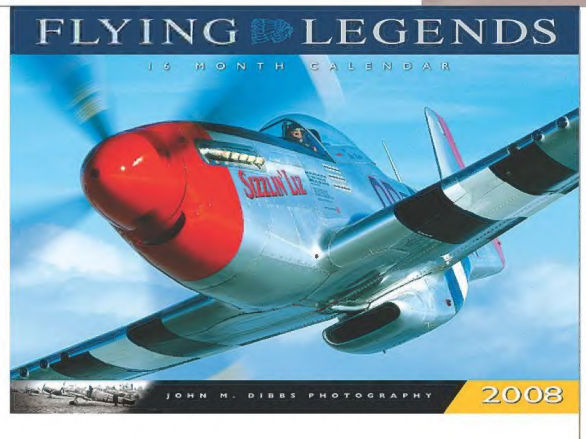
Photographs of air racing at Reno, Nevada. $14.99. Also available at *www.legacycalendars.com*.

Air to Air: Warbirds

Photographs by Paul Bowen. $14.95.

Air Power

Photographs from CheckSix. $14.95.



Flying Legends

Photographs by John Dibbs. $14.95.

>>> Credits <<<

Space Shuttle Guest Book. When Richard G. Van Treuren is not recovering and processing space shuttles, he is chasing blimps as editor of *The Noon Balloon*, the newsletter of the Naval Airship Association.

Music to Fly By. David Lande, who writes about aviation history, served on the staff of the National World War II Memorial in Washington, D.C.

Air Racing 101. An old-school air racer, Larry Lowe learned the basics from fellow competitor Bob Downey during his first Formula One race in 1978.

What the Red Baron Never Knew. Pilot Peter Garrison is the author of two columns for *Flying* magazine. He also evaluates automobiles for *Condé Nast Traveler*.

Mr B's Big Plan. Geoffrey Little wrote about hypersonic research in the September 2007 issue.

Unconventional Weapon. Bill Sweetman is the new editor-in-chief at *Defense Technology International* and the winner of the 2007 Aerospace Journalist of the Year Award for military coverage.

How Things Work: Chandra X-Ray Telescope. Damond Benningfield is a freelance science writer and radio producer in Austin, Texas.

Out in the Breezy. Jason Paur received an Aircraft Owners and Pilots Association Karant Award for his 2006 radio profile of Carl Unger. This is his first feature for *Air & Space*.

Restoration: Fleet Model 8. Lemuel C. Shattuck works as a cropduster on the Great Plains.

My Other Car Is a Podcopter. Mark Gatlin writes frequently about military aviation.

Blast From the Past. Paul Hoversten is the executive editor at *Air & Space*.

Forecast

IN THE WINGS AND ON THE WEB...

IN THE NEXT ISSUE

FROM STORIED FIGHTER aircraft of World War II to engine technology that may one day revolutionize private jets, the next issue of *Air & Space/Smithsonian* has something for every air and space enthusiast.

Tiny Turbine A retired jet-engine designer is pushing a startling way to power private airplanes.

Spitfires and Hurricanes We report on two London-area efforts to bring the icons of the Battle of Britain back to life.

The Man Behind the Planes of Fame A Chino, California museum that Ed Maloney built to preserve legendary airplanes has become a legend itself. Here's how it all began.

DOUG FISHER/WARBIRD DEPOT

Steve Hinton in a P-26A leads a quartet from the Planes of Fame Air Museum. Behind him (left to right): an AT-12, a P-51D, and an F-86F.

Kibo: Japan's Space Station Module Former NASA astronaut Dan Barry explains Japan's plans for space.

Coming to *www.airspacemag.com* in December: See the courses at the championship Reno Air Races. Also, we test-drive the Allegro 2000 light sport aircraft.

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(Signed) Ed Dequina
Business Manager
Smithsonian Media Group

Safety in Numbers

RECORDS FOR SPEED, altitude, and distance help us measure progress in aviation, and they're worth celebrating. But commercial aviation in the United States has been setting records that deserve equal, if not greater, recognition: records for safety. It's a different kind of progress; we look for numbers like the fatal accident rate to get smaller instead of larger.

Achieving zero fatalities takes hard work on the part of people who fly and maintain scheduled airliners, but it also comes about through improvements in the aircraft themselves. The industry began keeping accident data in 1927, and back then, the aircraft were far more subject to accidents due to weather, poor visibility, and malfunctions of the airplane's systems, especially the powerplants. Aircraft engines, unlike those in cars, operate at constant high-power settings; for takeoff and initial climb, they need to run for short periods at their highest rated power. Reliability was a challenge.

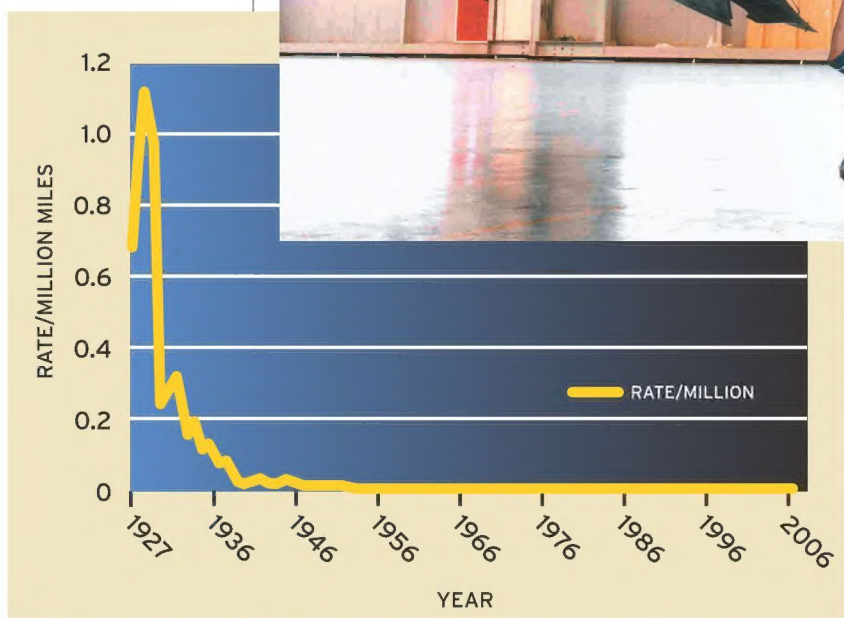
As airlines learned more about operating the reciprocating engines of the piston era, they established flying and maintaining procedures that led to a reduction in malfunctions. Airline maintainers would take a radial engine like the Pratt & Whitney R-2800 off the wing for an overhaul after it had run only several hundred hours. Engine manufacturers earned praise for improving the engines part by part and deriving ever-higher horsepower from them without risking breakdown. Eventually, though, elementary physics took over and horsepower requirements exceeded the recip's capacity. Cylinder size reached an upper limit, and the only solution—increasing the number of cylinders—led to the development of complex monsters like the R-4360.

And then the jet engine arrived.

To gain an insight into the contribution the turbojet and its successor, the turbofan, made to scheduled air carriers, compare the record of the R-2800 with a Rolls-Royce RB211-535 on the wing of one of Icelandair's Boeing 757s, which has operated for 40,000 hours without removal. And General Electric statistics that say its CF6 and CFM56 (with Snecma) experience only about 18 inflight shutdowns per million departures (most are precautionary). Engine stoppages, fairly routine with recips, are so rare now that GE says most pilots will never experience one in their flying careers.

So here's to the jet engine. It has made airplanes go faster, farther, and higher. But best of all, safer. For a complete table of U.S. airline safety statistics, visit *www.airlines.org/economics/specialtopics/SafetyRecordOfCarriers.htm.*

GEORGE C. LARSON, MEMBER, NAA



The introduction of the jet engine (above, a Rolls-Royce RB211-535) dramatically cut airlines' fatal accident rate.

CHART: AIR TRANSPORT ASSOCIATION BASED ON NTSB DATA; TOP: ROLLS-ROYCE